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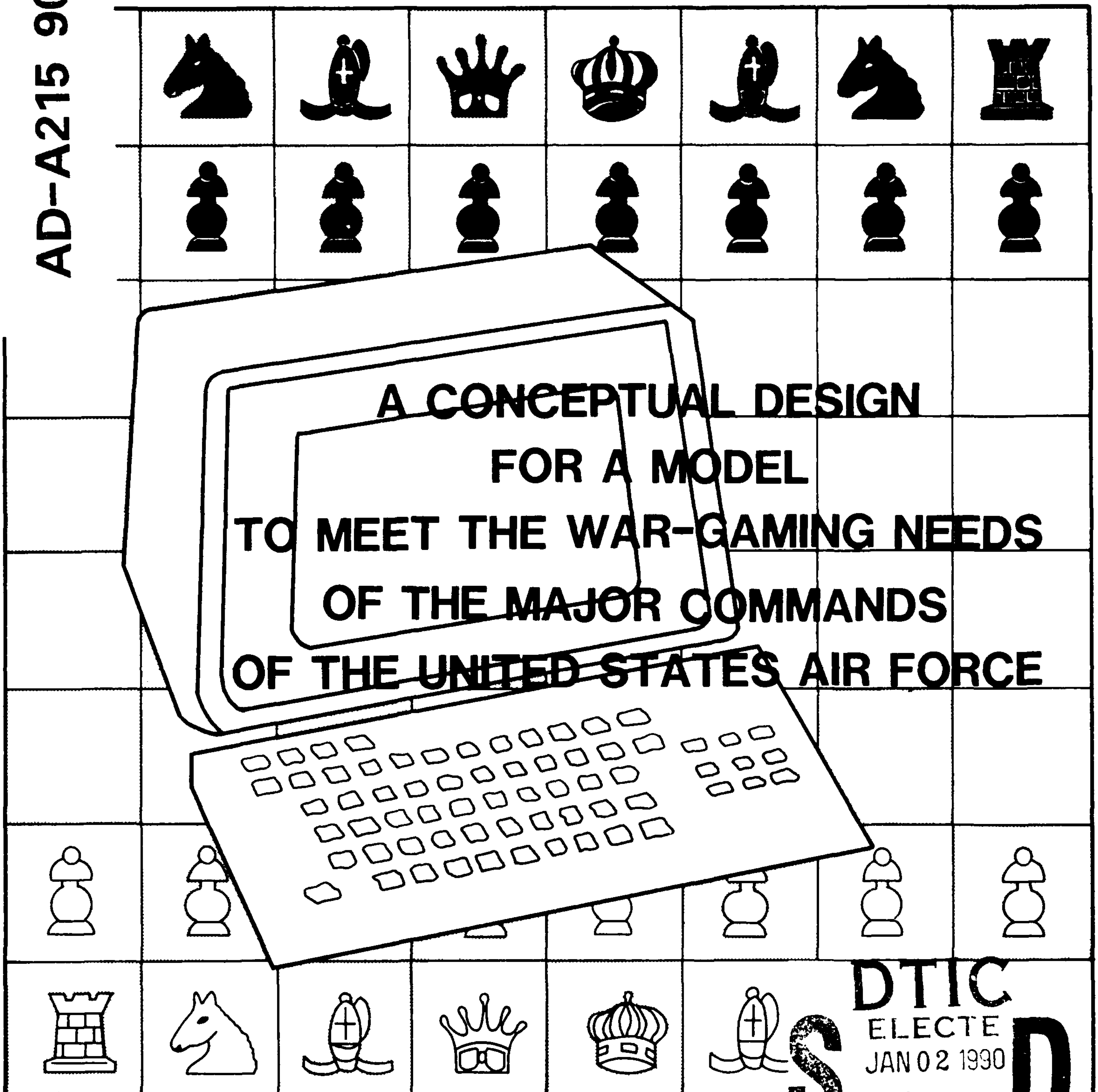

A CONCEPTUAL DESIGN FOR A MODEL TO MEET THE WAR-GAMING NEEDS OF THE MAJOR COMMANDS OF THE UNITED STATES AIR FORCE

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Research Report No. AU-ARI-84-8

A CONCEPTUAL DESIGN FOR A MODEL TO MEET THE WAR-GAMING NEEDS OF THE MAJOR COMMANDS OF THE UNITED STATES AIR FORCE

by

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Air University Press
Maxwell Air Force Base, Alabama 36112-5532

July 1985

After you have read the research report, please give us your frank opinion on the contents. All comments--large or small, complimentary or caustic--will be gratefully appreciated. Mail them to: CADRE/RI, Maxwell AFB AL 36112.

Cut Along Dotted Line

Thank you for your ass.stance

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In memory of my brother,

DONALD K. FOX

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FOREWORD

The advantages of providing synthetic war experiences to commanders at all levels through computerized war games has become increasingly apparent. Several initiatives are under way in the Air Force to provide new and expanded war-gaming opportunities. One of these initiatives is the Command Readiness Exercise System (CRES) which is to provide not only expanded war-gaming capabilities for students in professional military education courses but is to provide an all new capability for operational war gaming to high level commanders of the major commands. This system will be operated by the Air Force Wargaming Center as a part of the Center for Aerospace Doctrine, Research, and Education (CADRE).

In this research report Lieutenant Colonel Fox begins by reviewing the history of war gaming and giving an overview of the status of hardware and software developments relevant to war gaming. He goes on to discuss very real limitations that are an inherent characteristic of any war game. In the light of these limitations, the author examines potential applications for the Air Force Wargaming Center and makes recommendations for implementation as part of the CRES. As significant as what is recommended are those activities recommended against and the reasons for recommending against them.

This report should be read by all individuals involved in setting up any war-gaming capability, conducting war games, or incorporating war games into an education or training program. Anyone seriously interested in playing war games or concerned with what can or should be learned in the course of playing a war game is well advised to read at least the first three chapters.

Donald D. Stevens

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ABOUT THE AUTHOR

Lt Col Daniel B. Fox is a research fellow in the Airpower Research Institute, at the Air University Center for Aerospace Doctrine, Research, and Education (CADRE). He holds a BS in Engineering Physics, a MS in industrial engineering, and a PhD in mechanical engineering. With over 16 years in the Air Force as operations research analyst he has extensive experience with computer systems ranging from massive mainframes to microcomputers. He has worked on computer models of communications and intelligence systems, tactical employment of air forces, strategic weapons effects, and logistics systems. Major Fox has participated in and observed war games at the Air Command and Staff College as well as the Army, Navy, and Air War Colleges. He has played the role of the red air commander in the theater war exercise used in the combined air warfare course at Air University.

PREFACE

The funding of the Air Force Command Readiness Exercise System (CRES) is a recognition of the need for a comprehensive Air Force war-gaming facility. The three-phase CRES program includes war games for Air Force professional military education, joint war games between senior service schools and operational war games for the Air Force major commands.

In this research I have examined positive and negative aspects of war gaming from both a historical and a pragmatic perspective. I have attempted to outline salient features of war gaming that we should strive to take advantage of and pitfalls of war gaming that we must avoid.

This research report is recommended for any persons involved in the production or use of war games.

Daniel B Fox

Daniel B. Fox, Lt Col, USAF
Research Fellow
Airpower Research Institute

CHAPTER 1

INTRODUCTION

The 1975 Clements Blue Ribbon Panel Report on Excellence in Professional Military Education (PME) and the August 1976 Air Force chief of staff constant readiness tasking called for the development of intensive courses and innovative methods to instruct students in war fighting. In response, the United States Air Force has embarked upon a multiphase project to establish a comprehensive, computerized, war-gaming capability. This project, known as the Command Readiness Exercise System (CRES), is located at Maxwell Air Force Base, Alabama. The CRES development is under the operational control of Air University's Center for Aerospace Doctrine, Research, and Education (CADRE) and will be housed in the newly created Air Force Wargaming Center (AFWC).

There are three phases of CRES, the first two having a similar objective. The first phase is to use the AFWC to upgrade the war-gaming capability of the PME schools at Maxwell AFB. The second phase is to provide joint war-gaming capability by integrating the AFWC with similar gaming facilities at the Naval War College, the Army War College, and the National Defense University.

The third phase of CRES will provide operational gaming capability for the major commands (MAJCOMs) and separate operating agencies (SOAs) of the Air Force. By researching in depth this third phase, a major theme emerges; the operational gaming mission of the AFWC is qualitatively different from the PME mission. Indeed, the role of war gaming in education is familiar to many and the positive aspects are self-evident. Conversely, operational gaming is a more controversial application of war gaming. Both the positive and the negative aspects of operational gaming are matters of debate.

Purpose

The purpose of this research is to explore the positive and negative features of war games and to examine how these features relate to potential applications of phase three of the CRES. In an effort to assess both the true potential and inherent limitations of the AFWC for problem solving at the MAJCOM and SOA level, the author intends his research to

be inclusive rather than exclusive. That is, the attempt is to include as many potential applications as possible under the umbrella of an AFWC. Which applications the Air Force actually implements is contingent upon the relative availability of funds and the total number and type of requests from MAJCOM and SOA customers to the AFWC. As will be seen, a most critical aspect is the involvement of the customers in defining the needed capabilities.

Definitions

The distinction between models, simulations, and war games was once a simple matter. In the past, a model could be defined as "a small object, usually built to scale, that represents another, often larger object," [1]* whereas a simulation could be considered as an "operating representation of selected features of real-world or hypothetical events and processes." [21, p. 1-1] Finally, a war game was "an imaginary military operation usually conducted on a map and employing various movable devices intended to represent the opposing forces, which are moved about according to rules reflecting conditions of actual warfare." [7]

Emerging technology, especially the digital computer, has forced changes in the common usages of these three terms. The ability to calculate rapidly and accurately has allowed the assembly of complex mathematical structures that, when computed, may yield information about the behavior of the real world. Hence, we must come to grips with the concept of a mathematical or computer model that is, in many ways, different from a physical model. Even the original definition of a war game involved varying degrees of simulation since war games have always reflected selected features of real war. The relatively recent introduction of computer models to simulate various actual or hypothetical wartime conditions under intensive scrutiny is a major step forward in the history of war gaming.

Certainly a useful thought to reflect upon when grappling with the concept of modeling is that the purpose of the model is to solve some problem by reaching some decision. Such an approach entails a systematic progression of events. First, the modelers abstract the essential features of the problem to create a model. Specifically, this process involves a selection of those elements deemed most important in terms of the problem at hand. Second, the modelers provide various inputs to the model and manipulate

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* Numbers in square brackets ([ ]) refer to items in the notes which are at the end of this report.

these variables in the synthetic model environment to yield observable results. The third phase involves interpretation of these synthetically derived results so as to anticipate more effectively real-world results. Impacting this interpretation process are the underlying assumptions used to create the model and other available information not incorporated into the model. Figure 1-1 illustrates this paradigm. Interpretation of the results yields a decision, or a set of potential decisions, for further analysis.

Such an evolutionary process is familiar to students of historical trends. Advances in technology, in this case the computer, continue to blur distinctions that once seemed clear and render definitive answers impossible.

Despite such difficulties, it is important to remember that models, particularly mathematical or computer models, pervade simulations and war games. In other words, every simulation or war game inherently reflects some aspect of the environment, the principal actors in this environment, and the interactions of these actors with each other and with the environment. This representation, that is the model, always requires validation of underlying assumptions and supporting data. The validity aspect of modeling, particularly in war games, is taken up in detail in chapter 3.

Although war games are simulations, simulations of wars need not always be war games. This distinction between war games and simulations, while somewhat artificial, is made on the following basis. In simulations explicit rules and procedures within the simulation help define available choices and decisions. Conversely, in war games, players interactively make the pivotal decisions and choices. In this context, war games are simulations with participatory user interaction. The use of this discriminator is not wholly satisfactory because technology, in the form of artificial intelligence, can make simulations appear much like war games. In addition, some simulations that provide interruption points to examine the status of events and the modification of governing parameters do seem to blur this particular distinction between simulations and war games. Nonetheless, such a distinction remains useful in defining these two terms.

Perhaps an equally compelling way to view those terms is to emphasize the fact that simulations and war games exist on a continuum extending from military field exercises at one end of the scale to analytical models at the other. Such an approach provides a taxonomy of combat models.

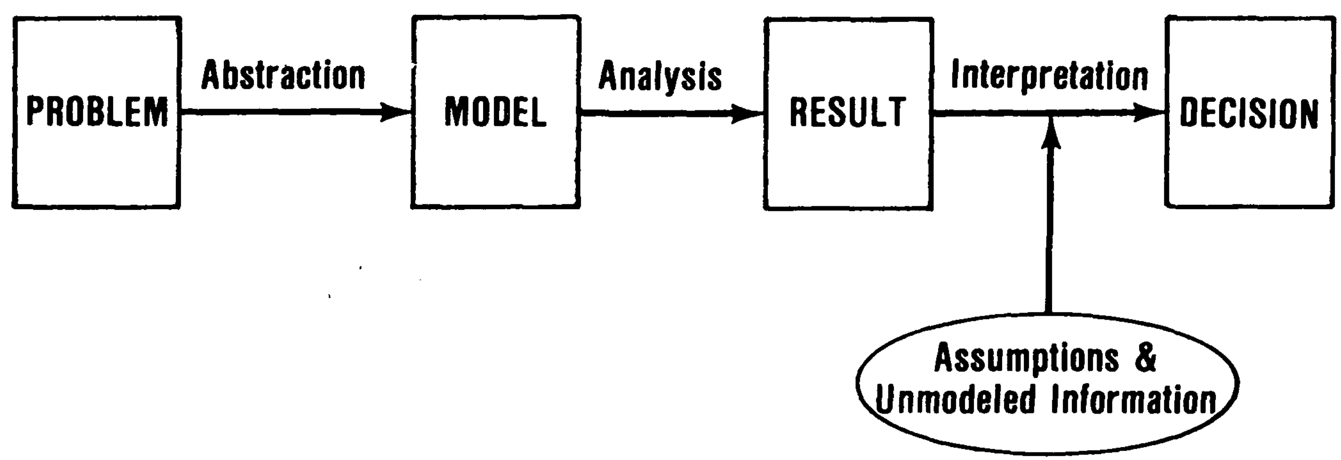

Figure 1-1. Paradigm of Model Usage

Taxonomy of Combat Models

The participants in the Theater-Level Gaming and Analysis Workshop for Force Planning held in 1977 proposed a taxonomy of combat models. [20, p. 5] The workshop participants labeled one of the three dimensions used in the taxonomy "technique." Along the technique axis they arrayed the following alternatives arranged in decreasing order of degree of human interaction:

Military exercises
Manual war games
Computer-assisted war games
Interactive computer war games
Computer simulations
Analytic models

In addition, the workshop participants identified a second dimension of the taxonomy as "scope." Along the scope axis they arrayed, in decreasing order of area of operations:

Global- or theater-level conflict
Major battle in theater
Local many on many engagement
Local one-on-one duel

Finally, they labeled the third dimension of the taxonomy "application." It is not clear that any ordering is implied (or appropriate) here but the labels of the various applications are convenient for the purposes of discussion. The labels used were:

Force planning
Research, management, and evaluation
Operational planning
Training and education

Figure 1-2 illustrates this taxonomy. Moreover, in order to forestall possible confusion over the use of the terms in this taxonomy, the meanings, for the purposes of this report, require further clarification.

1. Military exercises: The maneuver of troops in the field.

2. Manual war games: Games using stylized maps (boards) or ordinary maps to represent battle scenes.

3. Computer-assisted war games: As manual war games but with the aid of a computer to determine outcomes and/or keep track of men or material.

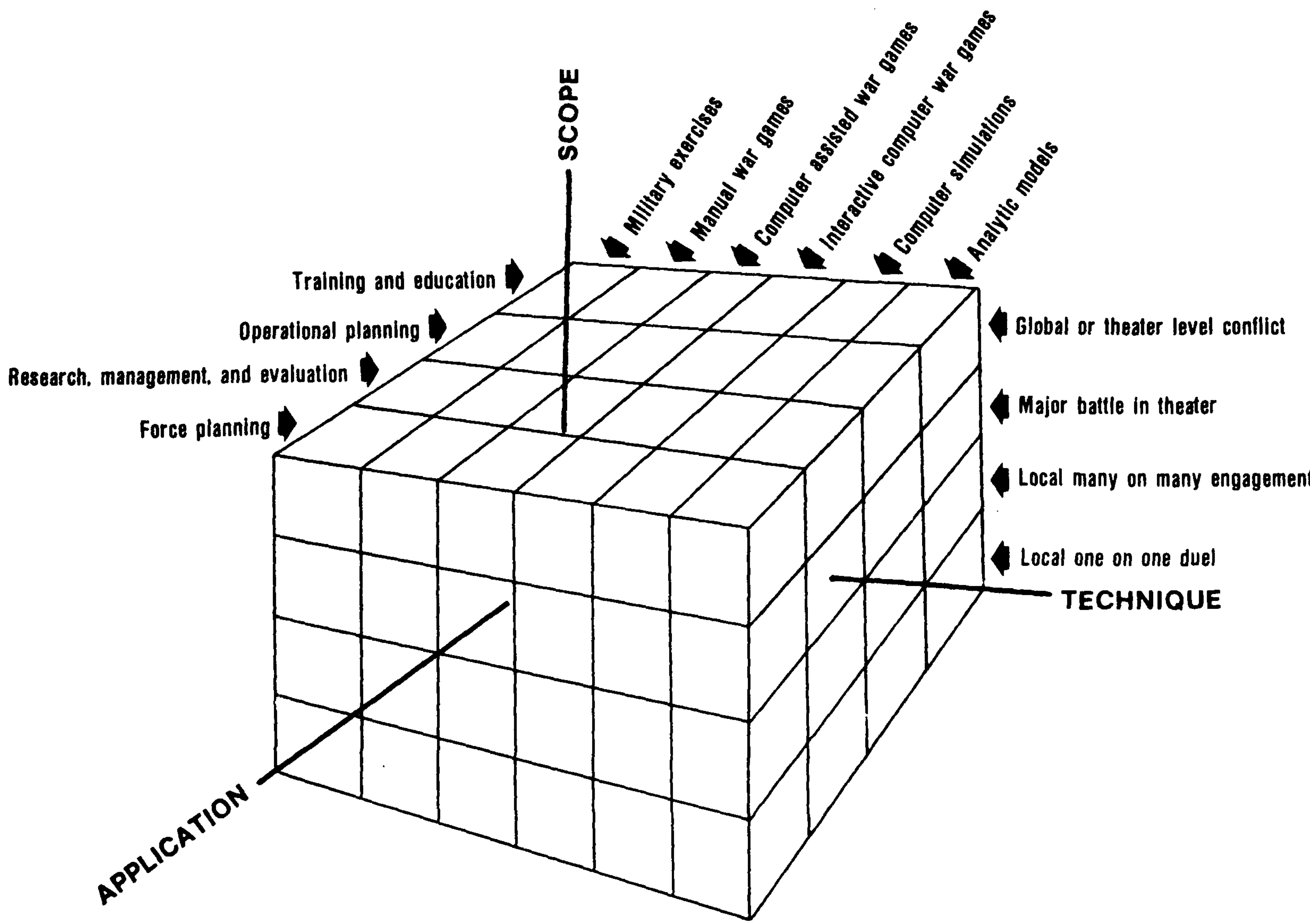

Figure 1-2. Taxonomy of War-Gaming Models

4. Interactive computer war games: Similar to computer-assisted war games but with the main emphasis now on the computer and computer products. Other items, such as a maps or game boards are only of ancillary importance and interest to participants.

5. Computer simulations: Autonomous packages with all user specifications made prior to beginning the simulation. There is no human decision making except as may be simulated within the program.

6. Analytic models: Differ from simulation models in the representation of the modeled entities. The simulation model has a degree of correspondence between elements modeled and the simulation model not found in analytic models. The analytic model is rather a more abstract, purely mathematical representation of outcomes.

7. Global- or theater-level conflict: A conflict with outcomes of interest involving the globe or an entire battle theater.

8. Major battle in theater: A conflict with outcomes of interest within a single battle within a theater.

9. Local many-on-many engagement: A conflict with outcomes of interest involving many units but not an entire battle.

10. Local one-on-one duel: A conflict with outcomes of interest involving just one unit or element of a unit (for example tank, aircraft, or artillery) fighting one other unit or element.

11. Force planning: The use of results to evaluate doctrine to explore alternative investments in potential future weapon systems.

12. Research, management, and evaluation: The use of results to test doctrine, employment concepts, or weapons.

13. Operational planning: The use of results to evaluate war plans.

14. Training and education: The actual use of war gaming or analysis to reinforce desired lessons.

The concept for phase three of CRES developed as a result of this research will be presented in the context of this taxonomy. This will provide a framework for establishing what CRES does and does not entail.

History of War Gaming

By way of a brief overview, in reviewing the history of war gaming, it is convenient to recognize four distinct eras.* Historians consider the first, from before written history until the early 1800s, the war-chess era. War game participants of this era played with chesslike pieces on boards having varying number of squares according to fixed rules. Players used these games apparently as much for amusement as for training for war.

The second era, until about 1875, was a period of manual war games played on a map or representation of terrain. A major characteristic of these games was the voluminous rules that specified all aspects of the games; for example, how fast a force could move over various terrain, what maneuvers were permissible, and how to calculate attrition. The extensive rules required considerable familiarization before a game could be played and then the play proceeded relatively slowly because of simultaneous record keeping and calculation. War gamers refer to these types of games as "rigid" war games due to their inherent inflexibility.

In the third era, lasting until after World War I, dissatisfaction with the lengthy and complex rules led to a freer form of gaming. Although retaining most of the paraphernalia of second-era games--the map, or terrain table, and the movable pieces--these games replaced most of the rules on movement and losses with the military judgment of an umpire. Free play allowed faster progress, made it easier to incorporate the effects of new weapons, and permitted a wider variety of considerations to enter into the games.

The fourth, and present era, which began after World War I, has focused on the expanded role of war games into research. During this most recent period, war games have achieved a new measure of respectability, having played an expanded role in peacetime planning. The most dramatic

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* There is an excellent synopsis of the history of war gaming in Andrew Wilson's The Bomb and the Computer. [27] The bulk of the following history is from Wilson's book with additional information included from John P. Young's A Survey of Historical Developments in War Games [28], Alfred Hausrath's Venture Simulation in War, Business, and Politics [17] and Raymond Livingston's Review of Problem Areas in the U.S. Army Combat Modeling Committee and Examination of War Games Currently Used as Training Devices by Active Army Units. [18]

break from past war-gaming experience was the introduction and application of digital computers.

Turning now to a more detailed history, ancient Eastern civilizations, including the Chinese, Indians, and Japanese, apparently had war games 3,000 to 4,000 years ago. Archaeologists have discovered representations of soldiers and war equipment in ancient Egyptian tombs as well as in Greece, Persia, and India, all of which predate written history. The Japanese game of Go originated in China about 3000 B.C. as Wei-Hai. The guiding principle of the game was to follow the teachings of Sun-Tzu, especially his maneuvers for outflanking an opponent. In fact, even today the Chinese name Wei-Hai means encirclement.

In contrast, the Hindu game of Chaturanga used a stylized map (playing board) and pieces representing foot soldiers, light cavalry, and elephants. This game used dice to determine the outcome of moves by the four players. There is historic speculation that the pacifist Brahmans sought to use the game as a humanitarian alternative to actual combat. When Europeans imported Chaturanga, they simplified the game into its present form of the game of chess.

Indeed, seventeenth century aficionados developed a number of chesslike games. These games included knight and castle pieces from chess as well as pieces representing pikemen, halberdiers, and bowmen. One of these, King's Game, developed in 1644 by Christopher Weikhmann in Ulm, saw extensive use as a practical aid in military training. Another game, War Chess, played on a board of 1,666 squares, helped train military officers of Germany, France, Austria, and Italy.

In 1811, a little over a century and a half later, Herr von Reisswitz, a civilian in Berlin, invented what most contemporary war gamers would recognize as a war game. The equipment included a sand table representation of terrain and colored paper attached to small blocks of wood to represent troops. Two young princes told the Prussian king of the game, and under the sponsorship of the crown, an improved edition, using a plaster relief terrain table and porcelain pieces, became operational. The son of Alexander I, later Czar Nicholas, played this same game in Russia.

Subsequent development of this game occurred when, in 1824, von Reisswitz's son, a lieutenant in the Prussian Guard artillery, replaced the relief model with a large-scale map and developed an improved set of rules more reflective of actual battle. Players used metal pieces in scale with the map, with the opposing forces designated red and blue--a convention still observed in most war games. An umpire used dice with varying numbers of sides in

conjunction with tables of numbers in order to determine outcomes and to assess battle losses.

This improved variant eventually came to the attention of the Prussian chief of staff, General Karl von Muffling. With some reluctance von Muffling agreed to observe the game. After getting involved in the game von Muffling exclaimed: "It's not a game at all, it's training for war. I shall recommend it enthusiastically to the whole army." [26]

In 1828, Count von Moltke the elder, as a lieutenant, became quite enamored of Reisswitz's game, called Kriegsspiel by the Germans. By 1850, von Moltke was president of one of the Kriegsspiel clubs that sprang up to promote interest in the game. In 1857, when von Moltke became chief of the German General Staff, he promoted Kriegsspiel as one of the best ways to teach military officers how to employ their forces in battle.

By 1875, Russian officers, too, received instruction in war games (often called map maneuvers) as a supplement to exercises and lectures on tactics. In 1903, the Russian military mandated that war games be used to train higher ranking officers on garrison duty or at the General Staff. The most serious problem preventing the effective use of war games in Russia was the lack of experienced umpires. Because of this deficiency, many games failed to live up to expectations.

In time, von Reisswitz's improved game spread to virtually every country with a standing military. Professional groups formed to play Kriegsspiel, handbooks were published, and prominent professional military men served as umpires. The role of the umpire in the game grew in importance as the need for professional judgment in specifying the outcomes of gamed battlefield encounters increased.

During this period, one of the greatest proponents of war games was Alfred Graf Schlieffen, chief of the German General Staff from 1892 until 1906. With the aid of extensive war-game experimentation, the General Staff developed a series of "Schlieffen Plans" for the invasion of Belgium and France in World War I.

After World War I, the stringent restrictions on German troop strength made war gaming of considerable interest to the Weimar military. The emphasis clearly had now moved away from rigid games played with strict rules toward the more free style of play, relying on an umpire's operational experience. In 1929, General Erich von Manstein played the first war game that gave really serious attention to the

political consequences of decisions. This was the forerunner of the political/military game now played by policy makers worldwide.

Under Hitler, the use of war games flourished. After the invasion of Poland, the operational experience obtained in the field proved useful in refining war games. In fact, the smoothness of at least the initial phases of the German invasion of France through Belgium is attributed to the wealth of detailed knowledge obtained by the unit commanders. This knowledge was derived, in large part, from extensive war-game experience. Other German war games revealed the tremendous difficulties associated with the proposed assault on Great Britain. Awareness of those difficulties no doubt contributed to Germany's decision to not attempt the actual invasion. One amazing story from German World War II war-game experience concerns a game to evaluate defensive strategy for the German Fifth Army against the American Seventh Army in the Ardennes. The German Staff continued the war game, which coincidentally they had begun just before the actual American attack, using reports from the field as enemy inputs to generate the actual operational orders sent to the field.

In contrast to the German experience, US reliance on, and experience with, war gaming was slight. In 1883, Major W. R. Livermore published a war game entitled The American Kriegsspiel. Livermore's rules encompassed "Tactical, Grand Tactical, Strategical, Fortress, and Naval games." In 1914, the game was still being used in the United States.* War gaming was not confined to the land. In 1887, William McCarty Little, a retired naval lieutenant, presented a series of six lectures on war games at the US Naval War College at Newport. These probably would have passed with minimal notice but for the president of the Naval War College, Captain Alfred T. Mahan. Because of Mahan's interest, three levels of war games came into use at the Naval War College. The first, involving a duel played between opposing single ships, proved useful, for example, in examining the effects of varying the turning radius of battleships. The next level, a tactical fleet game, required perhaps 12 persons and used individual model sailing ships with red and blue hulls and sails of various colors to represent different types of ships. The third, a strategic game, was of even larger scope. The commander in chief and the staff for each team directed operations from separate rooms. This particular game involved maneuver and

* For example, the December 5th, 1914 issue of Scientific American contains an enthusiastic exposition on the use of Kriegsspiel at the Army War College in Washington D.C., [10, p. 470-471]

position of large forces, with termination occurring once the opposing forces came into contact. The game would then be continued but as a tactical fleet game.

The US Navy is credited with considerable foresight due to war gaming of World War II action in the Pacific. In 1951, Admiral Nimitz told students at the Naval War College:

> The war with Japan has been re-enacted in the game room here by so many people and in so many different ways that nothing that happened during the war was a surprise--absolutely nothing except the Kamikaze tactics towards the end of the war; we had not visualized those. [21, p. 2-54]

The admiral, however, made no mention of the failure to anticipate Pearl Harbor.

For their part, the Japanese made extensive use of war games for planning World War II. Prior to the war, the Total War Research Institute in Tokyo played sophisticated three-sided political/military games. The three-sided games allowed for differing national aims and coalitions with friendly and enemy forces. The Japanese used those games to prepare a timetable for the occupation of Malaya, Burma, the Dutch East Indies, and the Central Pacific islands.

In May 1942, Admiral Yamamoto, the Japanese combined fleet commander in chief, held a war game of far-reaching scope. The Japanese plan in the game included the invasion of Midway Island and the capture of the Aleutians, New Caledonia, and the Fiji Islands. In addition, there were to be air strikes against Sydney, Australia, and a full-scale assault on Hawaii.

Since World War II, the biggest change in the technology of war games has been the introduction of the digital computer. Areas where the computer is extremely useful in war gaming are keeping track of forces and equipment, movement, situation display, and damage assessment. More specifically, the computer is very useful in the massive bookkeeping required to keep track of the location and status of men and equipment simulated in modern war games. Calculating losses of men and material also can be speeded by incorporating the desired model into the computer program. In this way, it is possible to circumvent the delays associated with rigid war-game play without making the game totally dependent upon the experience (or whim) of the umpire.

Modern Use of War Games in the United States

The taxonomy of combat models presented earlier intimates that war games can span the applications of force planning, research, management and evaluation, operational planning, and training and education. Which of these applications of war games are currently being pursued in the US military establishment? The biggest usage of war games is for education and training. The National War College, the Naval War College, the Army War College, and the Air War College all have offices whose primary responsibility is to present war games to students at these institutions. As already indicated, the Navy has played war games at the Naval War College since before the turn of the century. It is not surprising, therefore, that the Navy has led the services in applying computer technology to war games for a number of years. A series of recent upgrades to the Naval War College war-gaming system means that the US Navy has one of the most modern war-gaming facilities in the world today. For its part, the Army has used war games since before there was an Army War College. The war gamers at the Army War College are currently engaged in an ambitious effort to upgrade war-game facilities so as to provide a more comprehensive war-gaming experience to their students. The Air War College uses a number of war games in its curriculum, including the theater warfare exercise (TWX), which is an introduction to air operations in the European theater. Air University has undertaken an ambitious, multiphased war-gaming development project, the Command Readiness Exercise System (CRES). The first phase of CRES is an attempt by the Air Force to upgrade war-gaming capabilities for all of the professional military education (PME) schools, including the Air War College.

Elsewhere in the Air Force, those tasked to provide operational planning at command level are much more likely to use an analytical method or simulation than war gaming because the resource demands, especially in terms of manpower and time, of an interactive war game are generally too high to allow routine use. For example, Military Airlift Command (MAC) uses many analytical models and quite a number of simulations, primarily within the Operations Research Division within the plans shop (HQMAC/XP). The flow generator (FLOGEN) model (currently FLOGEN III) and the massive M-14 simulation of the MAC airlift system see regular use in MAC planning.

Further up the chain of command, at the Office of the Joint Chiefs of Staff, there is an organization called the joint analysis directorate (JAD) that previously held the likely sounding title of Studies Analysis and Gaming Agency (OJCS/SAGA). The analysis performed in this organization is primarily of studies already completed. However, OJCS/JAD

does sponsor some military/political games. These are free-form games used primarily as a sophisticated way of brainstorming potential crises in order to expand the scope of potential policy alternatives to be available.

From the Air Force perspective, then, the current uses of war games are thus dichotomous. They serve primarily for educating and training mid-level officers on the way up but also at the very highest levels within the Department of Defense (DOD) where they serve as think pieces in political/military settings.

CHAPTER 2

STATE OF THE ART

This chapter briefly discusses, in a nontutorial way, the state of the art in computer hardware and software available to war gamers. The chapter has three main sections. The first, examines modern computer hardware capabilities and discusses the application of this hardware to computerized war games. The second section examines some selected general software issues. The third section provides a short discussion of some current state-of-the-art war games.

Hardware

In the fewer than 40 years since the initial introduction of digital computers, new technology has greatly expanded computer capabilities but at decreased monetary costs. It is now possible to buy for a few hundred dollars a desktop computer that far exceeds the capabilities of the early computers, which occupied whole rooms and cost millions of dollars. In turn, there are computers available that cost millions of dollars but have capabilities that were unimagined when scientists introduced the first computers. There also has been a concomitant increase in the capability of devices attached to computers. Local area network communication and graphics-oriented input/output devices now make possible a more natural interface between humans and the computer.

Computational Capacities

Computer scientists measure the capacity of modern computers to perform calculations in millions of instructions per second (MIPS). This provides only a very rough measure of capability but can serve as one guide in comparing computers. Today, even a modest computer system has the capability to execute tens of MIPS. Some current personal desktop computers compute at a rate of one half of MIPS. The fastest modern computers, the so-called super computers, can achieve hundreds of MIPS. The capabilities of both desktop computers and super computers may be expected to increase in the near term.

Color Graphics

One of the most visually impressive devices available for computer output is the color graphic display terminal. Over the last few years, the cost of these devices has dropped dramatically while the level of detail that can be represented has gone up. Vendors advertise the level of detail presented on a graphic display in terms of the number of picture elements* (pixels) that appear on the display terminal. Color display terminals that provide from 4 to 16 colors on an array of approximately 200 by 200 pixels are available for under $1,000. Such devices are capable of succinctly presenting a great deal of information. Higher resolution devices, presenting approximately 500 by 500 pixels in 16 or more colors, are currently under $10,000. The advantage of these higher resolution devices is that map representations, for example, are much more realistic. At this level of resolution, a contour map on the screen looks very much like a color contour map that a troop commander in the field might use. Even higher resolution devices are now appearing in the marketplace. A 1,000 by 1,000 pixel device capable of displaying more colors than the human eye can distinguish is now available.

Graphics Input Devices

The light pen, similar in physical appearance to a ballpoint pen, is an electronic device used in conjunction with a graphical display screen. When the pen touches a video display screen, the electronics associated with the light pen can detect the specific pixel being pointed at by the pen.

A digitizer tablet is another graphics pointing device that generally uses one of two types of hand-held pointers. One pointer is slightly smaller than a package of cigarettes, the other looks like a ballpoint pen. In either case, when the operator moves the pointer over the surface of a specially prepared electronic board, the electronics connected to the computer can determine the position of the pointing device on the board. The board may be as small as 12 inches square or as large as 3 by 4 feet.

A joystick is a familiar device to aficionados of video games. It is simply a vertical handle, fixed at the base,

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*A picture element (pixel) is simply a dot of light on the display screen. Thus a 200 by 200 pixel display consists of 200 rows of dots, each row consisting of 200 dots of light. On a color display, of course, each dot can be illuminated in any of several colors.

capable of rotation about the two horizontal axes. The internal electronics can send a signal to a computer indicating the position of the joystick.

A track ball is a variation on the joystick that uses a ball approximately 4 inches in diameter. The ball is mounted in a box with the top one-third of the ball exposed. The user rotates the ball analogously to moving a joystick.

A mouse is essentially a track ball turned upside down. The ball is usually smaller, and instead of the user's fingers directly rotating the ball, friction with the desktop accomplishes the same end.

All of these graphics input devices have similar utility. This is because a computer program can establish a natural correspondence between the setting of the device and a location on a graphics screen. The position on the graphics screen corresponding to the current pointer position can be indicated by displaying a special symbol on the display. Further, the pointer is useful, for example, in indicating a route of travel by pointing to successive points on a map or in selecting from a menu of options offered by a computer program. One advantage of the digitizer tablet over the light pen is that the operator's hands never obscure display while it is in use.

Local Area Networks

Another technological advance of potential worth to computerized war gaming is local area networks (LAN). The internal representation of data in different computers often varies. This creates problems when users of one computer want to share data with users of another computer. A LAN connects two or more computers (the network part) that are within reasonable physical proximity (the local part) of each other. A LAN allows for automated data sharing between computers by defining a protocol for exchange of data to which all connected machines are made to adhere. The protocol allows data to be exchanged between computers having different data formats. The concept of what constitutes "local" is not well defined and is evolving as the technology advances. Certainly, the interconnection of any computers in the various buildings around Chennault Circle at Air University, for example, would constitute a local area network.

Impacts of the Hardware

Let us examine each of these hardware developments, in turn, and see how they can be used to advantage in a war-

gaming environment. First, the increased computational capacity available in modern computers allows the players to run very complex computer programs, perhaps representing an elaborate war game model. Not only is it possible to run these complex programs but, importantly for a war game, computers are fast enough to respond to the players on an interactive (time sharing*) rather than an overnight (batch+) basis. The elaborate models provide players a perceived degree of realism that might otherwise be missing. Interaction can create a sense of immediacy that, in turn, induces a high degree of motivation in players.

Another visual motivator is the color graphic displays that provide a medium for information transfer to war-game players that is dynamic and of high density. Computers can produce battle maps simulating those that might be available to an on-scene commander. Even more importantly, it is relatively simple to instruct the computer to overlay additional information on such maps. Although a theater-level battle commander might actually use parts of his or her staff to annotate maps, a theater-level war game, involving only a dozen or so people, must use a less labor-intensive method to update displays.

Graphics pointing devices can simplify the tedious portions of data entry to a war game. Whereas an actual theater-level war involves literally hundreds of people in directing the actual forces, a theater war game might involve only a dozen personnel. Hence, less labor-intensive methods of directing forces must be employed so as to make the game more practical. For example, when players can use a graphics pointing device to identify such specific locations on a graphics display as lines of communication, the pace of the war game is greatly accelerated. Further, these devices significantly reduce the time required to train users in the mechanics of operating a war game, thereby permitting more time to accomplish the ends of the game.

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*Interactive or time-share computing refers to a environment where the computer responds to individual inputs by the user. Thus, the user can see the results of previous inputs before entering additional commands.

+Batch computing requires the user to prepare all inputs to the program to be run before running the program. An entire job, detailing what program is to be run and all data or commands for the program, is submitted to be executed without further user intervention. The turnaround time, or time from job submission until the user receives output from the program, can vary from minutes to weeks.

The capabilities of local area networks and microcomputers produce a synergy well-suited for the war-gaming environment. Today's microcomputers are many times more capable then early mainframe computers. Among the advantages of microcomputers are user friendliness,* responsiveness, and diminished telecommunication requirements. By combining microcomputer and LAN technology, it is possible to take advantage of the unique capabilities of the microcomputer and still retain the economies of scale associated with large, central processing computers. The players can use the microcomputer to operate the color graphics displays and pointing devices and to perform validity checks on user inputs. Only after the user input appears correct is the information transmitted, via a LAN, to a mainframe computer in order to perform the complex calculations of the war game model. Outputs, from which updated graphic displays are produced, are returned to the microcomputer. (Microcomputers used in this way are often referred to as smart terminals.) By relieving the central computer of the tasks of responding to individual inputs and generating graphic displays, the mainframe computer can be more responsive to the major computation tasks remaining. Because of the many functions the smart terminals perform, a less powerful (and less expensive) central computer may suffice. Thus, it is possible to produce a distributed system consisting of many smart terminals and one or more central computers that, once linked, are more responsive and less costly than any alternative system with devices connected directly to a large central computer.

Software Techniques for War Games

Of the many techniques, tricks, and methods used in war gaming, three important developments stand out. They are the introduction of specialized modeling languages, rule- or knowledge-based systems, and modular and hierarcnal modeling techniques.

*There is no generally accepted definition of "user friendly" but the concept embraces a range of features to help reduce user anxiety. Providing the ability to easily recover from erroneous inputs, making available on-line help and instilling a sense in the user of being in control all contribute to this end. These features are more prevalent in microcomputer programs than in programs run on mainframe computers.

Specialized Modeling Languages

In the early days of digital computers, each different computer had to be programmed in its own specific language. Even new follow-on computer models from the same manufacturer had different languages. This technological impediment created significant problems when a computer user decided to upgrade to a different, more capable or reliable computer. The attendant costs of translating computer programs from the language of one machine to that of another soon became a major factor impacting these upgrade decisions.

Fortunately for computer users there gradually evolved some standardized languages in which to write programs. Although computers did not inherently understand these standardized languages, clever programmers could write a "translator" (usually called a compiler) for translating a standard language into the specific language of a computer. Thus, any computer for which an appropriate compiler had been written could be used to run programs written in the standardized language. Although this is an oversimplification of the real-world problems faced by people trying to upgrade their computer equipment, the concept remains inherently valid.

As a result of this technological advance, different standardized languages became popular for various classes of programs. For example, the common business-oriented language (COBOL) has had a long association with business data processing applications. The formula translator (FORTRAN) language introduced by International Business Machines Corporation (IBM) has dominated scientific computing. Other standardized languages, some with significant advantages over FORTRAN, have since been proposed, but none have achieved the ubiquity of FORTRAN. Consequently, virtually every computer used for scientific applications and, even more importantly, virtually every programmer involved in scientific work, is familiar with the FORTRAN language. Given the scientific analysis heritage of war gaming, it is not surprising that many computerized war games use FORTRAN.

Computer languages specifically designed for computer modeling are a comparatively recent development. These languages, for example, the general purpose simulation system (GPSS), queuing, graphical evaluation and review technique (QGERT), or simulation scripting (SIMSCRIPT) offer two primary advantages over a more general purpose language such as FORTRAN. First, modeling languages offer built-in methods for automatically collecting routine data on the system being modeled. For example, in an air war model it is typically possible to request that the simulation

language automatically collect data and plot the attrition of various aircraft types as a function of time. This results in significant savings in programming effort because, in a FORTRAN simulation or game, perhaps one-third of the programming effort is for data collection. Second, modeling languages typically contain programming constructs that enable models to be expressed more succinctly than in a general purpose language. The combination of automatic data collection facilities and compact modeling constructs means that a program written in a specialized modeling language will be much smaller than one written in FORTRAN. This is advantageous not only in the initial model development stage but in subsequent phases when further modifications are necessary to update the model or correct errors. Another advantage of using a more compact model in a specialized modeling language is that it is easier for new personnel to grasp and thus more economical to maintain over the life of the model. Balanced against this maintenance advantage is the disadvantage of the having to train personnel to use the specialized modeling language.

Modular and Hierarchal Systems

A second area of software technology is that of modular and hierarchal systems. Modular, in the context of computer programming, refers to a style of programing where the programmer carefully restricts different functions of a program to specific portions, or modules, of the overall computer program. The different modules communicate only in restricted ways as necessary to integrate them into the overall purpose of the program. By strictly controlling communications between modules, programmers minimize the unintended effects of one module on another, a frequent cause of program errors. Modularity is advantageous also because it is easier to upgrade or to replace a module since each module performs a single function and its communication with the rest of the program is readily apparent. This seemingly simple expedient took many years to win widespread acceptance among programmers. Modular programming techniques are useful also for application to another important technique for war games, hierarchal models.

The driving force for a hierarchy of simulation or war-gaming models is the desire for a compatible set of tools, permitting the examination of the same scenario at various levels of detail. The key words here are "compatible" and "various levels." The various levels refer to the degree of aggregation or disaggregation (detail) incorporated in the model. For example, in war games examining a NATO versus Warsaw Pact conventional war in Europe, it is conceivable to have a war game from the perspective of the theater-level commander or a war game of specific engagements of the same

conventional war from the perspective of a unit commander. In those two games, the representations of weapon effects, logistics, and battlefield topography in the models would be quite different. A desirable feature of such war games, however, would be that the sum total of the results from many engagements modeled in detail by unit-level war games equal the result of the same scenario played out in the more aggregated theater-level war game. Unfortunately, with most models it is extremely difficult to relate the outcomes represented in detailed games to the outcome of a higher level game. This is because the two models have no common basis. If they did, the outcome in the higher level game could be related to the sum of outcomes in lower level games of the same scenario. This is the thrust of the US Army Model Improvement Program.

Early in 1979, the US Army conducted a critical review of the status of Army analysis capabilities. As a part of this effort a review panel attempted to define what they termed "an idealized analysis structure." [16, p. 3-8] One of the important statements made in defining this conceptual structure was:

> Recent advances in simulation technology such as the discipline of top-down structured programming coupled with added experience of the analysis community in development of a wide variety of simulation tools have led to general agreement that a *simulation hierarchy* . . . is both desirable and possible. [16, p. 3-12]

Hence, in its final report, the Army panel proposed a completely integrated structure. Figure 2-1, a reproduction of that structure, includes a hierarchy of games and simulations and a hierarchy of analytic models melded into a comprehensive, compatible, and integrated whole.

Artificial Intelligence

One of the dreams of the "keepers of the faith" in the realm of computer applications is to put together a computer that is demonstrably intelligent. This has proven to be an extremely elusive goal because, as anyone who has actually had to program a computer can verify, computers are literal to a fault. Computers will do exactly as instructed even when it should be obvious that the instructions are faulty. Attempts to rectify this absurd situation are part of a field called artificial intelligence.

One fruitful area of artificial intelligence is knowledge-based systems, also referred to as rule-based systems. Research in this area attempts to program a

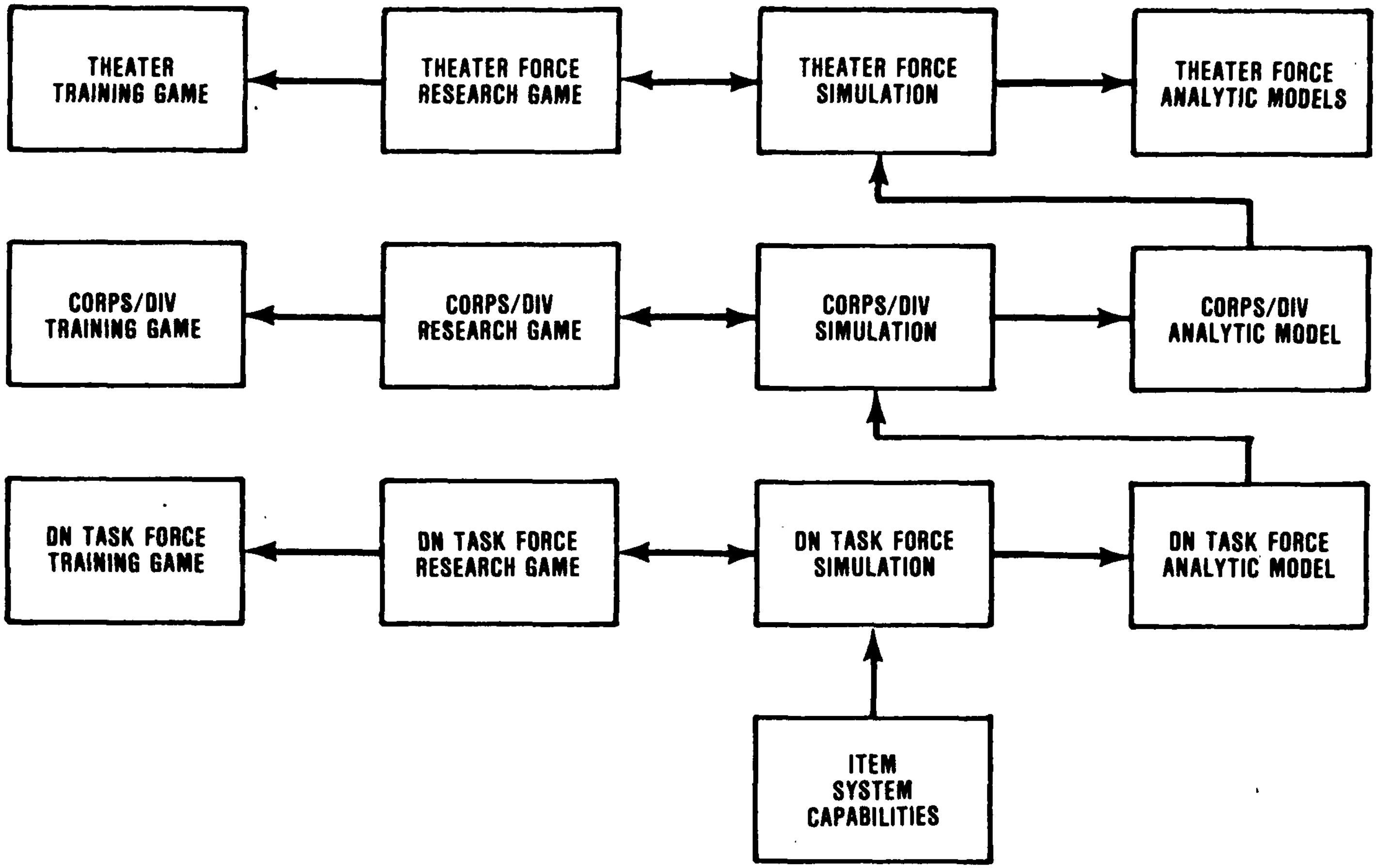

Figure 2-1. Hierarchy of War Games, Simulations, and Analytic Models

computer to respond, in an apparent rational way, to structured decision-making environments. Many prototypes and a few production systems along this line have been developed. One demonstrated success in this area was the creation of a medical expert system for the diagnosis of disease. [3 and 24] What, one may ask, is the relationship of medical differentiations (such as between osteomyelitis and poliomyelitis) to war games? In order to establish the relationship, it is necessary to consider the role of the enemy (red side) commander in war games.

One difficulty faced by designers of war games is how to provide a credible opposition commander. Two methods predominate. One is to use a player to maneuver the red forces. This can provide realism, particularly if the player for red forces studies and adheres to established red doctrine. In a detailed theater-level model, however, it is virtually impossible for one player to make all the moves necessary to portray a realistic scenario. Adding additional members to the red team can correct this deficiency, but when the red team grows to the size of the blue team, the manpower requirements of a game are effectively doubled, thereby greatly inflating the attendant cost of conducting the game. Another alternative is to preprogram the red forces to act in consonance with perceived red doctrine. This may be done successfully for early action, but as the scenario develops, the lack of response by red forces to changes in the battle situation becomes increasingly unrealistic. Ad hoc attempts to include alternative red actions based upon some gross indicator of the battle situation only slightly delay the inevitable failure of the red forces to act in a way appropriate to the scenario.

The use of rule- or knowledge-based artificial intelligence techniques has been employed only recently in an effort to provide for credible red command activity. This technique attempts to harness artificial intelligence technology to capture the essentials of a doctrine. The first of three contemporary applications of this technique is the Integrated Nuclear and Conventional Theater Warfare Simulation (INWARS) model, written by BDM Corporation for the US Army Concept Analysis Agency. INWARS is a general war model that examines doctrine and decision-making issues primarily in a theater nuclear, chemical, and conventional context. According to the description of INWARS from the OJCS/SAGA Catalog of Wargaming and Military Simulation Models:

> The emphasis in the model is on decision making with each headquarters at corps level and above represented by an entity which makes decisions and plans. This is accomplished using a knowledge

> based technique. . . . These headquarters units make plans for ground operations, develop targeting plans, monitor the performance of subordinates, and react to contingencies. [22, p. 371]

A second model using a similar technique is TAC Brawler, written by Decision Science Applications, Inc., for Air Force Studies and Analysis. TAC Brawler simulates multiple aircraft air combat. Again quoting from the OJCS/SAGA catalog:

> Each simulated pilot owns his own mental model in which he may observe changes in his environment and exchange message traffic with other members of his flight. . . . This technique [artificial intelligence] allows the pilot to consider numerous options for his next maneuver, predict the consequences of employing that maneuver for the near term, appropriately score the results of such a maneuver, then select the maneuver which scores the highest. [22, p. 699]

By far the most ambitious effort using this method is the Rand Strategic Assessment Center (RSAC) whose director, Dr Paul Davis, states that with this technique

> the rules governing national behaviors are the model's explicit variables. The rules reflect expert judgment; where experts disagree we carry along alternative rule sets -- referring, for example, to the different rule sets for Soviet and U.S. automatons as representing different "Ivans" and "Sams." [13, p. 3]

Succinctly, what this approach provides is a structured method by which reasonable command and control of forces can be modeled.

Modern War-Gaming Models

This chapter's third and final section discusses four war-gaming systems currently in development. These include the aforementioned Rand Strategic Assessment Center, the US Readiness Command (REDCOM) joint theater-level simulation (JTLS), OJCS/SAGA joint analytic warfare system (JAWS), and the Lawrence Livermore Laboratory Janus system. Each of these systems provides lessons best not forgotten in implementing the Command Readiness Exercise System.

Rand Strategic Assessment Center

Although more details on the potential of artificial intelligence can be found in a Rand interim report [13], several advantages of using this approach in the Rand Strategic Assessment Center are readily discernible. The first, and most obvious, advantage is the practical usefulness of the model itself in providing for actions of forces in a war game. Rule-based modeling not only can provide a credible opponent but also can provide for realistic actions of intermediate and lower command levels of friendly forces. This frees the players operating at the highest echelons of command from having to enter detailed instructions into the computer for every level of command in the game.

A second important advantage of the rule-based modeling technique used in RSAC is reproducibility. When war games use human players to act as commanders, it is difficult to conduct experiments to test the effects of changes in any specific parameter. If the same players play multiple games while varying the parameter of interest, the effects of the players' learning about the game may mask the results of any change in parameters. Conversely, if different players are used from play to play, then the variation in decision making among the players again is likely to mask the actual effects of changes in operating parameters. Because the rule-based system reacts in a reproducible way to game situations, this obviates this particular problem.

A third, less obvious, advantage of the modeling method is that to create a reasonable rule base that captures a doctrine requires a thoughtful introspective of the rationale for that doctrine. Such a structured examination of either enemy or US doctrine represents a worthwhile end in itself. Observing the ramifications of the rule set in playing out a war game will, in turn, contribute additional insight into the efficiency and logic of that doctrine. Such insight may well serve as a further catalyst in prompting experiments with different rule sets representing variations in doctrine. This iterative scheme should contribute to a greater understanding of the effects of both US and enemy actions and beliefs.

Joint Theater-Level Simulation

In 1982 representatives from the US REDCOM, the US Army Concepts Analysis Agency, and the US Army War College agreed that a war game incorporating joint operations could be very beneficial for evaluating future plans. The Army War College intended to use the same program for educational purposes. To realize such a capability, these agencies

embarked on the development of the joint theater-level simulation (JTLS).

JTLS was an evolutionary rather than revolutionary because of its heavy reliance upon the long-used educational war game, McClintic Theater Model (MTM). The developers of JTLS hoped for many additional, new capabilities over those available in MTM, and most of the representatives of the interested agencies thought these new capabilities to be low risk in terms of their implementation. [23, p. 4-2 thru 4-7] The very tight schedule proposed for creating JTLS reflected the optimism of the representatives, including those responsible for writing the computer program. The schedule proved impossible to meet. although JTLS may yet prove to be a valuable war-gaming system, it will not be available until long after its initially desired date.

Joint Analytic Warfare System

In October 1983, the OJCS/SAGA (now OJCS/JAD) released a request for proposal (RFP) calling for a comprehensive war-gaming system. According to the RFP, the objective of the joint analytic warfare system (JAWS) is to support OJCS activities, including noncrisis, global responsibilities as well as real-time crisis management of local conflicts. [5] The first application, noncrisis planning, is a well-accepted application of gaming and simulation. The second, management of a crisis in real time, is more problematical. Moreover, there is an insidious danger in this application since additional information useful to a decision maker in a crisis situation, though welcome, affects how quickly the decision maker can respond. Incorporating the additional staff required to operate a JAWS system into a crisis management team could result in fatal delay. Hence, gaming and simulation in real-time crisis management represents an, as yet, unproven resource. It remains to be shown whether or not this particular approach can be brought to bear. To the credit of the authors of the JAWS RFP, the prescribed role of JAWS in crisis management concentrates on analysis and development of options to assist senior decision makers. In sum, one of the largest technological risks of the JAWS system is in providing a system flexible and responsive enough to meet real-time requirements.

Janus

Janus is a modern war game developed by a cadre of specialists headed by Donald K. Blumenthal at the Lawrence Livermore Laboratory. Janus features state of the art, color graphic displays and a user interface simplified by the use of a graphics-tablet pointing device. The internal

models of Janus are detailed to the point that a game consumes most of the capacity of a Digital Electronics Corporation model VAX 11/780 computer. In fact, the level of detail is so high that only a subtheater level of operations can be undertaken. It is in terms of ease of play, realism, and player motivation that Janus represents a quantum step forward in war-gaming technology.

CHAPTER 3

LIMITATIONS OF WAR GAMES

This chapter discusses the limitations of war games, first by introducing the concept of a "squishy" problem (as opposed to a rigorously quantifiable problem) and examining how this concept impacts the use of models, simulations, and games (MSGs), and second by exploring some operational problems that continue to plague attempts to apply MSGs. Finally, the chapter examines some examples of practical problems historically experienced by users of war games to see the effects of these problems.

Rigorously Quantifiable versus "Squishy" Problems

The term "squishy" as it appears in the literature in reference to a problem [e.g. 6; p. 3] describes those difficulties found in empirical research that are ambiguously formulated. The concept of a squishy problem incorporates those problems over which there is substantive disagreement concerning which variables constitute the essence of a problem, or problems, where the relationships among these variables are imperfectly known. For example, determining the strategic forces necessary for the United States to deter nuclear war clearly qualifies as a squishy problem. Conversely, determining the impact point of a bomb dropped by an aircraft is an example of a rigorously quantifiable problem. The difference between a rigorously quantifiable and a squishy problem is not merely the degree of difficulty or complexity from a practical standpoint (although squishy problems are often difficult and complex). In order to appreciate this fundamental difference, it is necessary to examine, in detail, the above examples of these two types of problems, with particular emphasis on selecting an output measure, determining relevant variables, and defining the underlying model.

Consider first the rigorously quantifiable problem of determining the impact point of an air-dropped bomb. Because the output measure, the physical location of the bomb impact point, is so obvious, there is no the need for giving thought to selecting a measure.

Determining the variables and selecting the actual model are interrelated problems since the purpose to which the results will be put determines both of these. Also

critical are the underlying assumptions that can be made. For example, a simplifying assumption would be that the aircraft is in level flight at the time of bomb release. With this assumption, many variables can be eliminated from consideration. The critical variables might be limited then to the location, heading, and the forward velocity of the aircraft at the time of bomb release. Of course other factors may be important as well. Depending upon the accuracy desired, the weight and atmospheric drag characteristics of the bomb under a certain barometric pressure may be important. If the effects of the earth's rotation require consideration, the geographic latitude would be a necessary variable. The level of accuracy required, as determined by the overall purpose, determines the number of variables considered. For example, some relatively simple objective such as bombing-range safety, necessitates only a rough idea of where the bomb will fall in order to be sure that the bomb will, in fact, land within the confines of the bombing range. For this, a very simple model that assumes, among other factors, a flat earth and no wind would be adequate. For other purposes, involving the use of a technically sophisticated airborne weapon-delivery computer, a more complex model using all of the variables mentioned above (as well as others) would be required. There is an element of choice here in that many different variants of a model could be used. In any case, however, the basic model used will be based upon principles of classical physics, including Newtonian gravitation. This accepted theoretical basis is an important feature of a rigorously quantifiable problem.

Next, consider the problem of determining the level of strategic forces judged necessary by defense planners to deter nuclear war. Although in this case there is not an obvious output measure that is unequivocally correct, one way to measure success in deterrence would be to calculate the risk of failure, for example, the anticipated probability of enemy nuclear attack. Ignoring for the time being the problem of how to calculate this probability, there remains the interpretation difficulty of assessing accurately the meaning of the probability and determining whether a certain figure represents a success or a failure. If, for example, defense analysts concluded that there was a 50 percent probability of enemy nuclear attack in the next year, this would prove to be an unacceptable risk to a majority of those polled. In contrast, if there was a 1 percent (or 0.1 percent or 0.01 percent) probability of attack, it is difficult to state unequivocally whether or not that represents an acceptable risk.

Given that risk of the failure appears to be an adequate measure of performance and given that some degree of risk (expressed as a probability of deterrence failure)

represents the maximum acceptable risk, there is still a requirement to determine the variables of importance in the overall deterrence equation. Such capabilities as throw weight of enemy forces and numbers of warheads are factors in evaluating deterrence; moreover, they have the advantage of being reasonably easy to count. Such elements as weapon system reliability or the expected readiness level of either side are significant but more difficult to fathom; however, approximate estimates of these are possible. Other crucial variables impacting enemy intentions and reactions to our actions, including the potential for an inadvertent nuclear strike, are impossible to gauge with any degree of accuracy. The difficulty then is twofold: first, the selection of meaningful variables; and second, the definition of meaningful values for some of the unquantifiable variables. This second difficulty occurs because it takes one from the realm of the physical sciences to the world of the social sciences. Unlike such physical aspects of nature as temperature or velocity, there are no reasonable scales on which to measure intent, fear, or other human reactions. This being the case, dealing reasonably with this uncertainty is a serious, practical problem than cannot be minimized. Hence, unquantifiable variables are anotner characteristic of squishy problems.

Finally, given that it is possible to measure performance, list all relevant variables, and determine a level to associate with each respective variable, there remains the problem of selecting a model. Certainly, there are innumerable ways to combine counts of warheads, equipment reliabilities, and evaluations of enemy intentions. The question is: what is the appropriate way to combine them in order to calculate the probability of enemy attack? Even more fundamental is the issue of verifying a given model formulation that, on its face, appears to be a reasonable manipulation of the input variables. In fact, there is no adequate way to validate the accuracy of the model result. It is this validation issue that makes squishy problems fundamentally different from rigorously quantifiable ones.

The essence of model validation is to take a real-world situation, prepare inputs to the model corresponding to that situation, and then compare outputs of the model to the real world. When agreement occurs repeatedly between the model and the real world, the model is considered valid. In actual fact, validation is, like trust, a matter of degree. The validation process works well for rigorously defined problems, especially those where the variables can be readily observed or manipulated through experiments. The process does not work well for squishy problems precisely because of the characteristics that classify them as squishy. The inability to state a result unambiguously, or

to measure the variables, or even to determine which variables require measurement means that any history of experimental results provides only minimal assurance that any particular model accurately predicts results in the real world.

In any attempt at validation, it is also important to recognize that the problem of collecting data on war in the real world is more than just a practical problem of inadequate resources for a Herculean task. The number of unmeasurable, and hence uncontrollable, variables in any battle situation means that each battle is a unique situation with its own list of imponderables. Any data base constructed consists only of single samples of various situations. But because of the inherent variability of circumstances, such a data base does not allow for successful model validation. Indeed, until practitioners of the social sciences develop the tools that permit quantifying leadership, morale, or group cohesiveness, the process of model validation cannot even begin.

To summarize, the differences between a rigorously quantifiable and a squishy problem are:

(1) <u>clarity and measurability of the objective</u>. The rigorously quantifiable problem is likely to have an obvious objective that is measurable on an existing and accepted metric. Conversely, the squishy problem is likely to have an uncertain and even unmeasurable output.

(2) <u>ease of determining and measurability of variables</u>. For a rigorously quantifiable problem it is relatively simple to decide which variables need to be included in a model, and further, those variables can be measured on an existing and accepted metric. The squishy problem often involves philosophical doubt as to which variables are really important and how some of those variables can be measured.

(3) <u>confidence in the correctness and completeness of the underlying model</u>. A rigorously quantifiable problem is likely to have a model (or even a choice of models) founded on a firm theoretical base and verified by experiment. The squishy problem has no accepted theoretical basis for a model, and any proposed model is subject to criticism. Further, the model for a squishy problem is not subject to verification due, in part, to the lack of adequate measurement scales for variables believed to be important.

By now it should be obvious that the vast majority of problems to be addressed by MSGs is squishy. As such the use of MSGs (in the face of lack of demonstrable validity) poses serious problems. The difficulties in dealing with

squishy problems, as well as other difficulties, are highlighted repeatedly in the open literature.

Operational Problems

One of the most disturbing aspects of war-gaming limitations is the similarity and repetitiveness of the written criticism. In report after report, many of the same problems surface but with no significant progress indicated as to their ultimate solution. There has been quite a number of stinging indictments of the whole field of modeling, simulation, and gaming. A 1975 report, prepared as part of an overall Rand study of improved air-ground warfare analysis methods [25], emphasized those data and modeling problems involving the use and analysis of conventional forces. In 1977 a Workshop for Military Force Planning, sponsored by the Office of Naval Research, examined primarily theater-level gaming with the findings and recommendations documented in two volumes [19 and 20]. In 1979, Garry Brewer and Martin Shubik published a book based on information assembled in a three-year investigation of models, simulations, and games for the Defense Advanced Research Projects Agency (DARPA). [12] This book addresses a number of problems and questionable practices in the modeling, simulation, and gaming field. Also in 1979, a report was prepared and published by a special study group formed by the deputy chief of staff for Operations and Plans at Department of Army Headquarters [16], documented opportunities for more effective use of Army analysis resources. Many of the observations made by this particular special study group have implications for the analysis community at large. Finally, in 1980 the General Accounting Office (GAO) published a report discussing quantitative analysis methods and some of the problems in using such an analysis for public policy issues. [6] The report itself concentrates on Department of Defense (DOD) efforts to examine conventional ground and tactical Air Force requirements through the use of mathematical models. After reviewing some of these critiques, a number of issues stand out as being consistently identified as shortcomings of modeling and gaming.

The lack of validity was, as previously suggested, given as a major shortcoming of MSGs because there is a lack of a comprehensive theory concerning how to interpret real-world combat operations in the theoretical context of models, simulations, and games. The proclivity of model builders to add detail in an attempt to capture reality more accurately and to circumvent the need for further validation is identified as fruitless.

> Thus far, none of the attempts to create truly realistic representations of full-scale conflict has been successful. Piling detail on detail and complexity on complexity in an effort to capture reality has simply not resulted in anything useful or productive. [16]

Yet another aspect of validity, however, is that the underlying data base of the model is subject to errors. The most often cited problem is inadequate data. Also, the actual misuse of data, gathered for purposes other than those to which it is eventually put, and the necessity for subjective evaluations, both contribute to systematic errors in model results. The problems enumerated in the DOD Force Planning Data Base (DFPDB) are typical.

> Problems cited with the DFPDB included the large size of the data base, the lack of quality control over inputs, the existence of information gaps, the absence of standardized reporting procedures, and the institutional bias in certain data sources. [20, p. 18]

Another identified data problem is the use of engineering weapons test data to determine weapons effectiveness because, most often, operational test data for weapon systems under varying realistic conditions do not exist. [6] Other authors repeat this assertion.

> Little attention has been given to data validation; the data sets commonly used by operations modelers are seldom tested for the appropriateness to the intended application. [12, p. 73]

> A number or a set of numbers constituting "data" can be admixtures of subtle concepts, subjective evaluations, and limited but hard evidence based on actual physical testing. The particular testing, however, may have been undertaken for purposes remote from the use that another study makes of the data. [25]

The lack of validated data leads to reliance on assertions like: this model uses the "only known data;" or "these are standard data;" or even, this model and data were "used this way in previous studies." [12, p. 73] Used this way, war games lend what Wilson calls "a wholly specious scientific aura" to analysis. [27, p. 25]

Insufficient validated data contributes to yet another problem, the proclivity for modelers and gamers to use the outputs of one (unverified) model as inputs (data) to

another model. [25] This "incestuous relationship" among models complicates any assessment of the results of MSGs by further limiting the transparency of the model or visibility of assumptions built into the results. Inadequate documentation exacerbates this lack of transparency.

Certainly, the history of modeling reveals that poor documentation produces poor results. The Military Force Planning Workshop commented on this problem in the following way:

> The inadequacy of model documentation in presenting the underlying assumptions made in model design and the development of algorithms, is a particularly important shortcoming when a model is considered for application to problems beyond that for which it was initially developed. [20]

The GAO has issued a series of reports critical of the documentation of computer programs in general and of MSGs in particular. "There are no Government-wide ADP [automatic data processing] documentation standards." [2] "Documentation guidelines at federal agencies were still inadequate." [4] And in a sample of about 100 MSGs purchased by the federal government in New England, the GAO stated: "For about one-third of the MSGs where some joint usage was required or expected, documentation did not exist at all." [12, p. 192] Of the remaining two-thirds, documentation was poor and did, in fact, impeded efforts to convert the programs for use on another computer configuration with a different purpose. [4, p. 12] This documentation problem is not limited to the military.

> In 1975, a National Science Foundation study determined that only about 20 percent of the non-military models funded by the federal government could pass a minimal standard for documentation. [15]

The documentation problem is further aggravated by the ongoing process of model revision where war gamers add more detail and complexity in an effort to be more realistic. [6] This process may well render obsolete such documentation as may exist. In addition, personnel turnovers deplete the corporate knowledge base concerning details and assumptions in models used. This problem is especially acute in the military where normal rotation policies preclude long-term assignment. As the Army Models Review Committee pointed out:

> It became evident to the Committee members that in many cases the available documentation, together with discussions with the model groups, were

> inadequate to thoroughly evaluate the models. This was particularly true with regard to models that were developed some time ago and <u>where the original development team could no longer be identified</u>. In some cases, models have been used occasionally, then retired and then are used again by different individuals. <u>More continuity of personnel associated with a useful model is required</u>. [9, emphasis added]

Another critical theme pervading the literature of MSGs is their use in an advocacy role. The inherent "squishiness" of problems investigated and the intense competition among service programs encourage decision makers to seek all possible arguments in favor of their own position. Computer models, with their scientific aura, are often used to produce evidence supporting a particular position. Because assumptions and data input to the model are subject to manipulation, there is ample opportunity to use the model to produce the desired, supportive results. This opportunity has not been overlooked.

> At present, advocacy seems clearly to predominate over scientific evidence when choices are made about the construction and use of MSGs [models, simulations, and games]. [12, p. 191]

A contributing factor to the use (or abuse) of models and games in an advocacy role is the lack of a well-integrated system of peer review of modeling results and conclusions.

> At present, the academic community is not well integrated into the process [of military decision making] at any time during the life of the average MSG. . . . This state of affairs has been brought about jointly by the academic experts, who have eschewed responsibility for participating in military analysis, and by the military analysts, who have been reluctant to expose their analytic work to outside scrutiny. [12, p. 282]

> Detailed investigation of the obstacles to the creation and transmission of knowledge is needed to determine . . . the effect of classification on external review and scrutiny; and the extent to which classification is invoked to obscure the failures of questionable work. [12, p. 282]

It is not as if these problems have suddenly sprung into being in the modern-day applications of war games. These, and other problems, have continuously plagued the

users of war games. We turn now to a brief exposition on some historical examples of these problems.

Historical Abuses of War Games

In chapter 1, we mentioned Alfred Graf Schlieffen's use of war games to evaluate a series of plans for the World War I invasion of Belgium and France. These games indicated that the Germans needed massive manpower on the right wing. Moving this large number of personnel meant a sizable incursion into Belgium. Additional games played with a strengthened right wing showed the requirement for even more manpower. As a result, the Germans created an additional army corps using reservists. Under Schlieffen's direction, the German General Staff repeated variations of the plan, and no matter how much manpower was made available to the right flank, more personnel were needed. Although Schlieffen began to have doubts about the plan's feasibility, the Germans used the plan as the basis for their offensive. If this were the extent of the story, then one might conclude that the war games were accurate prognosticators of events, with the possible flaw being the failure to heed the lessons of the game. This is not, however, the full story.

Despite the multiple variations in the Schlieffen plan attempted, these games are notable for what they did not take into account. Consider the massive railroad-building effort in Europe that had transformed the meaning of maneuver of forces. Although the Germans paid considerable attention in these games to the capacity and bottlenecks of the German and Belgian railroads in transporting German offensive capacity to the front, they ignored the capacity of the French railroads to enhance the mobility of French defensive forces. In addition, the Germans failed to take into account the enhanced capabilities of the defense made possible by the introduction of the machine gun, rapid-firing artillery, and barbed wire. [27] This oversight occurred despite the fact that the defensive potential of these weapons had been demonstrated years earlier, in the Russian-Japanese war.

Perhaps even more important was the failure of the German war gamers to consider political factors as a determinant of the projected outcomes. The Germans quickly dismissed the thought that the Belgian military might attempt any resistance to the German incursion and treated the idea of British intervention either with derision or as a hoped for opportunity to teach the British a lesson. So complete was the general dismissal of the British threat that the actual decision by the British to commit troops after the German invasion threw the Kaiser into panic. [27, p. 24]

If there is a lesson to be taken from this, it is that unknowns cause the greatest deviations between predictions and reality. What might not be quite so obvious, however, is that there are two kinds of unknowns. First, there are ordinary unknowns representing factors that have been considered but that are known only imprecisely. Second, there are those factors that, for one reason or another, are not considered at all. Because decision makers do not see these "unknown unknowns," their omission can be catastrophic and, at a minimum, can make any analysis appear poorly done. From the perspective of hindsight, it appears that the German General Staff should have been aware of some of the aforementioned elements. The fact that such factors did not receive adequate consideration shows only that the staff lacked omniscience not competence. The war games designed and played by the German General Staff involved high-caliber, competent, and conscientious military minds. The major shortcoming of the plan itself was due to unknown unknowns. It is obvious that unknown unknowns are even more dangerous than the unknowns because there is no way to protect against them. No matter how thorough an analysis, there can be no assurance that all critical factors are evident and present.

Another example of unknown unknowns causing strategic catastrophe was the focused blindness of the French concentration on the Maginot Line before World War II. Once the French made the decision to build the line, virtually all analysis became defense oriented. [12, p. 55] Hence, the emphasis of French studies was on the necessary concrete thickness and weapon ranges to prevent a successful assault, ignoring other military developments that posed a threat to a static defense. Only from hindsight is it obvious that the effectiveness of German mobility should have been a major consideration, a fact the French overlooked at the time.

The Japanese provide an even more blatant example of the misapplication of war games. As previously mentioned, Admiral Yamamoto, the Japanese combined fleet commander in chief, played out a war game to evaluate an extensive Japanese Pacific offensive extending from Sydney, Australia to the Aleutian Islands. Japanese officers, upon learning of the plan, were shocked at its vast geographic scope. The dismissing of some commander's reservations by the high command, especially concerning the Midway operation, proved tragic for the Japanese because the lessons of the game were consistently ignored.

At one point in the game, American land-based aircraft attacked the main Japanese carrier force. The umpire ruled that the enemy had scored nine hits and two Japanese

carriers were sunk. Rear Admiral Ugaki, the presiding officer at the games, intervened to reduce the number of hits to three with just one carrier sunk. The following day the Admiral disallowed even the one sinking so that the previously sunken carrier participated in the next day's action. Other similar modifications of the umpire's rulings took place, always to the advantage of the Japanese forces. [2] As an interesting historical note, the actual devastation wreaked on the Japanese fleet four weeks later at the battle of Midway was even worse than had been originally ruled in the game. American carrier-based aircraft sunk four of only six existing big Japanese carriers, causing the proposed wide-ranging Japanese offensive to collapse.

The point of this discussion is not whether war games are accurate or even inaccurate but that war game results depend largely on judgment. In a free-form game that judgment is up front and visible, as in the case of Rear Admiral Ugaki overriding the judgment of the umpire. It should be clear from material discussed earlier that there is equally as much judgment exercised in determining what data and assumptions are to be used in mathematical MSGs. Given the degree of judgment exercised, there is opportunity to use the model, simulation or game (MSG) results to argue for a particular point of view. Assuredly, Admiral Ugaki did not act as he did in order to invite disaster upon the Japanese war effort. There is no doubt in the author's view, that he felt strongly about the operation's actual potential for success, and he was not about to allow a war game umpire to stand in the way of that success.

Unlike the extensive Japanese experience in war gaming, the Soviet use of war games prior to World War II was severely constrained by strategic doctrine imposed by Stalin. No attempt to counter this official position, including the use of war games to demonstrate the fatal flaws in its assumptions, was successful, in fact, such opposition usually resulted in quick personal tragedy for the perpetrators. [12, p. 56] Not surprisingly, there was little continued dissent and, in fact, the Soviet military made considerable efforts to demonstrate why the Stalinist concept of a forward defense would indeed work.

As a final example of the misapplication of MSGs, consider the British analysis of the German potential for strategic bombardment of English cities. In 1921, the British Air Staff analyzed World War I German bombardment, with the aim of predicting the effects of another conflict. The resulting, highly classified study concluded that casualties due to aerial bombardment of London would amount to 50 casualties per ton of ordnance dropped, with about one-third of the casualties being fatalities. [11, p. 304]

The Air Staff explicitly stated that results should be adjusted when applied to cities with lower population density than London. Nonetheless, in 1926, another committee in the Air Staff examined the medical effects of strategic bombing. Disregarding the source of the 50 casualties per ton parameter and ignoring the exhortation in the original report to adjust the figure downward for decreased population density, the committee computed new casualty figures. [11, p. 305] Influenced by German propaganda, the report estimated the throw weight of the German air force at 700 tons per day. It should be noted that the exquisite detail of the report contributed to its wide acceptance. Finally, security restrictions prevented the transmittal of the models themselves or the assumptions inherent in them. This action, of course, precluded any independent outside review. It is not surprising, therefore, that on the basis of the committee report, the British Home Office recommended preparations be made for mass burials because there would not be enough lumber available to build coffins for all killed. In April 1939, the Ministry of Health issued 1,000,000 extra death certificates based upon the evidence provided by the committee. [11, p. 306] Rumors soon circulated that raised the general level of public hysteria, which, in turn, may have limited the options of the government in the political arena. As Paul Bracken stated:

> If someone had asked Chamberlain in September 1938 of his opinion concerning strategic warfare models he would almost surely have replied that he did not concern himself with such "technical details." . . . Surely the context in which Chamberlain saw the threat of all-out war must have been influenced by the results of the Air Staff models which had diffused like some insidious disease throughout the government. [11, p. 307]

Thus, in the course of the British Air Staff medical committee investigation there were multiple missed opportunities for needed questions to be asked. The data used to support the 50 casualty per ton parameter included some figures that were not representative. Furthermore, at the peak of the Battle of Britain, the Luftwaffe actually was able to deliver only 150 tons per day, nowhere near the 700 tons predicted for an earlier, less capable air force. The acceptance of the 50 casualty per ton parameter is a classic example of how the results from one study are used to support another. The inflated throw weight attributed to the Luftwaffe was not necessarily an intelligence blunder but, more likely, a conservative estimate made in the face of uncertainty. Security classification posed an added impediment to needed peer review of results.

Conclusion

The most worrisome aspect of the material presented in this chapter reveals that every problem is still present in our current applications of MSGs. The basic problem is the inability to prove the validity of any comprehensive model. The desirable alternative is not to discontinue using MSGs but to use them wisely and to recognize and accept their limitations. This is the topic of the next chapter.

CHAPTER 4

APPLICATIONS OF WAR GAMES

In spite of the rather discouraging tone of chapter 3, models, simulations, and games (MSGs) can make valuable contributions. This chapter begins by examining briefly some of the positive aspects of MSGs. It then focuses more specifically on war games and considers a range of potential applications for an Air Force Wargaming Center (AFWC). Each potential application area is then evaluated in light of the limitations of war games identified in the preceding chapter.

Features of War Games

Given the great historical embarrassments suffered by MSG users, as exemplified in chapter 3, one might ask why anyone would even consider using them. This section will cover some overall positive aspects of MSG use.

A Method for Dealing with Complex Squishy Problems

There are a number of good reasons for using MSGs, not the least of which is that some situations are both squishy and sensitive and that MSGs represent the only formal decision aid available. Decisions that must be made concerning conventional and nuclear weapons, for example, entail huge monetary expenditures and on each decision may rest the fate of the future freedom of our nation. Each decision involves complex domestic and international political considerations as well as issues of technology, military effectiveness, and possible opponent countermoves.

It is little wonder that decision makers seek out any tool that can illuminate some aspects of a problem. Even if such a tool addresses only one aspect of the problem, for example, the military effectiveness of a proposed weapon system, and that aspect only within the boundaries of some specific assumptions of employment and enemy counteractions, the tool still can provide some information not previously available. If the tool can be exercised using a variety of assumptions, then it can generate information over a range of possibilities. Squishy military problems are difficult to analyze using MSGs, but there are few alternatives. Answers based on guesswork, or solely on unsupported

professional opinion, carry little weight either with the military hierarchy or with the committees of Congress responsible for funding national defense.

A Tool for Decomposing Difficult Problems

The fact that proper use of MSGs forces explicit consideration of the range of possibilities for any assumption can be construed as a strength. It provides a natural method for subdividing a problem into smaller parts. Using MSGs in this way, the decision maker can concentrate on one assumption at a time so as not to be overwhelmed by the sheer magnitude of a problem. By breaking down a problem into its various components, for instance, political, military, and economic, the decision maker can seek information on each of these aspects of the alternatives separately. This is not to say, for example, that the economic and political considerations of a problem are independent of one another; rather that this is a useful way to examine the impact of various assumptions for different facets of the problem. The decomposition of a mammoth problem into separate considerations, each of which can be evaluated and the results later combined, is an aid in maintaining perspective in the face of overwhelming complexity.

A Way to Conduct Constructive Brainstorming

Another constructive application of MSGs, and gaming in particular, is as a form of brainstorming to uncover aspects of a situation not initially apparent. By role playing in a realistic game, participants involved in a complex scenario can explore alternative policies, discover unexpected alternatives, and sometimes, anticipate outcomes that differ from those originally envisioned. One worthwhile outcome is that a game can serve as a forum for formally considering how participants in the real-world counterpart may react. Used in this way games can facilitate research to generate and test hypotheses concerning, for example, the process of international relations and the nature of crises.

Testing Operational Plans

Yet another useful application of MSG is in testing plans. A real-world situation that requires planning a complex sequence of actions and where there is available a realistic MSG is an obvious candidate for testing a proposed plan. By playing out the planned actions in the simulated environment of an MSG, we can gain insight into how the plan

will work in the real world. Note the emphasized aspects of hypothetical success of such testing.

On the basis of information in chapter 3, we do not hope for a fully validated MSG for any combat situation. First then, we must substitute for validity the weaker requirement that the MSG be realistic.* Second, the result of testing is insight, not a prediction of actual events. The outcome of the MSG can be considered an example of a possible outcome in the real world. This outcome should be judged in the light of other outcomes generated by changing assumptions in the MSG and by considering the simplifications of reality that were made in constructing the MSG. The insight gained by using an MSG to evaluate possible events in the exercise of a plan is not a substitute for careful coordination and detailed knowledge, but it is a useful adjunct to planning efforts.

Use as a Planning Tool

If an MSG can be used to evaluate a plan, the next logical step is to integrate plan evaluation into the planning process. If the interpretation of testing reveals deficiencies in the plan, these can be addressed in a second iteration. When the testing function is closely tied to the planning process and the planning, testing, and replanning cycle is used iteratively to produce a final plan, then the MSG have become not just testing tools but planning tools as well. For many complex scenarios such as providing logistics for a massive deployment of a military force or the mobilization of manpower, the use of an MSG to evaluate various aspects of a draft plan is the only reasonable way to assess the viability of the plan. The alternative of actually trying out the plan would be too costly and might not be practical politically in a peacetime environment. Furthermore, for a complex plan with many interdependent activities, even the most experienced individuals cannot give more than a superficial overall evaluation of problems likely to be encountered should execution of the plan be attempted.

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*Unlike the concept of a valid MSG, there is no generally accepted, formal definition of a realistic MSG. For our purposes, however, "realistic" may be taken to mean that the MSG produces believable results with clear traceability of the cause of the results. Even where counterintuitive outputs are obtained, they can be explained to the satisfaction of, and be accepted by, experts in the area represented by the MSG.

Again, the results of exercising plans with an MSG is only a sample of possible outcomes. A test of this kind does not prove that a plan is either deficient or sufficient, nor does it directly indicate what changes should be made to improve it. The greatest benefit of using an MSG in this way is that it points out general areas of the plan where refinement might be necessary. When the plan is modified and retested, it gives insight to the effects that the changes would have on the actual execution of the plan.

Helping to Bridge the Management - Leadership Gap

Another good application for MSGs, particularly war games, is to help bridge a basic dichotomy inherent in the objectives of the US military. These objectives as recently stated by the Secretary of Defense Caspar Weinberger, are:

> To deter military attack by the USSR and its allies against the United States, its allies, and other friendly countries; and to deter, or to counter, use of Soviet military power to coerce or intimidate our friends and allies.
>
> In the event of an attack, to deny the enemy his objectives and bring a rapid end to the conflict on terms favorable to our interests; and to maintain the political and territorial integrity of the United States and its allies. [8, p. 16]

The dichotomy in this mission statement manifests itself as a problem in attempting to structure the military to be able to accomplish effectively both the peacetime and wartime objectives. Of course, effective war-fighting capability is an essential part of deterrence; however, the effective and efficient accomplishment of the peacetime objective of deterrence requires a different management style and different leadership traits than does the actual prosecution of combat. Table 4-1 summarizes some of the major differences between a peacetime and a wartime military.

The key to being reasonably efficient in peacetime, yet effective should combat occur, is to be prepared to move from a management-oriented peacetime posture to a leadership-oriented wartime footing as smoothly and quickly as possible. Since our forces are not engaged in battle a majority of the time, they are organized for and have much experience in peacetime roles. Wartime experience is ephemeral and needs constant renewal. To sustain readiness requires that our active and reserve military personnel have as much experience as possible in war. The reality of the

Table 4-1

Peacetime Military Characteristics	Wartime Military Characteristics
Emphasis on efficiency	Emphasis on results
Performance by the book, regulations, enemy is the inspector	Get things done, enemy is the opposing force
Careful management of human and capital resources	Lead men and women to maximum performance under hardship
Defering of decisions until all possible information sources have been exhausted	Make time-sensitive decisions on the basis of what is now known

world is that, during peacetime, this experience must be obtained in some synthetic environment.

Field training exercises (FTXs), a form of synthetic battle experience, have been used by the military to good advantage. Large-scale FTXs, however, are expensive and require massive movement of men and war machines to a suitable location. Some of the benefits of an FTX to higher level commanders can be accrued at much less cost by using a command post exercise (CPX) where the masses of troops maneuvering in the field exist only on paper. In an elaborate CPX, considerable effort is required on the part of the umpires or control team to provide realistic feedback to the CPX players. It is logical to consider providing feedback to CPX players by using a computer to calculate possible outcomes. This is the format of a classical computer-assisted war game.

Applications for the Air Force Wargaming Center

This section will concentrate specifically on applications of the Air Force Wargaming Center (AFWC). To do this we must consider relevant portions of the taxonomy of combat models from chapter 1. In consonance with the charter for the Command Readiness Exercise System (CRES), this discussion will be limited to interactive computer war games from the "technique" axis of the taxonomy. The

remainder of the taxonomy then can be represented in two dimensions as in Figure 4-1. Of the remaining portion of the taxonomy, we will consider the potential for the AFWC for each of the labels of the "application" axis over the entire range of the "scope" axis.

From the foregoing chapters it should be obvious that some applications are more consistent with the inherent characteristics of war games than others. Of the four applications in the taxonomy, the area of training and education represents the most prevalent use of war games and is clearly well suited to the characteristics of games. Specifically, achieving educational objectives does not depend upon the absolute validity of the underlying war-game model.

Operational planning is an area where war gaming can contribute. However, the lessons of the past indicate that it is essential that users fully understand what a war game can and cannot provide. As long as a game is used for brainstorming and providing insight into potential problem areas and not for making absolute judgments as to whether a plan is or is not acceptable, profitable use is being made of the results.

As in operational planning, some applications of research, management, and evaluation can benefit from war gaming. Again, as in the case of operational planning, a most important distinction between use and abuse of a war game lies in the expectation of the user. When a game is used as a form of structured brainstorming and the results interpreted as one potential outcome rather than a prediction of probable results, the user is less likely to get into trouble.

In the author's opinion, force planning offers the least lucrative target for application of the AFWC. For this application the user is most likely to demand predictive results. Here lies the greatest potential for misinterpretation of war-game results because of the dependence on the validity of the models to provide absolute rather than relative answers. If the AFWC and CRES move into this area it should be done with much careful thought as to how to avoid the pitfalls described in earlier chapters.

Outside the context of the taxonomy, there is an additional application for the AFWC. That is to play a role as an agency for counteradvocacy in the field of modeling, simulating, and gaming. This exposition would be incomplete if it did not examine the potential contributions of the AFWC to that end.

Let us turn now to a more detailed examination of each of these application areas and consider examples of games that would make productive use of CRES and the AFWC. Keep in mind that the major concern of this research is the application of operational gaming and the role of the major commands (MAJCOMs) in the AFWC. The intent here is to illustrate some war-game applications of potential interest to the MAJCOMs. Bear in mind that these examples are illustrative, not exhaustive. The most useful operational gaming applications for the AFWC will come to light only when representatives from the MAJCOMs and the AFWC begin to meet on a regular basis and hold discussions that result in defining actual operational games.

Training and Education Applications

Resident professional military education (PME) applications for the Air Force Wargaming Center have received considerable attention from the staffs of the Squadron Officer School, the Air Command and Staff School, and the Air War College. For this reason, we will ignore applications of CRES and the AFWC to PME except to suggest that microcomputer-based war games be developed for use in the nonresident seminar and correspondence PME programs. Such games would offer some of the advantages of the resident programs to nonresident PME students.

The educational potential of the AFWC, however, is not limited to PME. Because advanced PME is available only to selected personnel over a restricted time and because it caters to a wide audience having diverse backgrounds, PME is restricted in what it can do. Therefore there are ample opportunities for war games that either address an audience not served by PME or that delve more deeply into a single topic than is feasible for the mixed backgrounds in a typical PME class.

The AFWC, for example, offers the opportunity to demonstrate to specialists in the Air Force how they fit into the larger scope of mission accomplishment. As a result of the growing sophistication of weapons, the Air Force has increasingly narrowed the job descriptions of the various Air Force specialty codes (AFSCs). Individuals in the Air Force tend to become more and more isolated from others outside their own fields. Participation in war games broadens knowledge and gives visibility to the part an individual plays in overall mission accomplishment. This, in turn, provides a sense of the importance of a job, instills pride, and can be a highly motivating influence. This motivation stems directly from the new perspectives provided by the war-game experience. In particular, the opportunity for players to participate in a game from the

perspective of a general officer provides valuable experience. In fact, the opportunity to participate in a game at one or two levels of supervision above one's current job gives an Air Force officer an appreciation for the complexity of the competing requirements that are part of that supervisory position.

One of the dangers of war gaming in an educational environment is that players may carry away the wrong lesson. For example, the fact that war games typically reward, with favorable outcomes, adherence to current employment doctrine may or may not be desirable. A war game is certainly an effective way to reinforce existing doctrine; however, the game may discourage players from trying new strategies or tactics. The results players obtain by trying new methods may be dismal, but due to limitations in the underlying model, the assessment may not be realistic. Widespread use of such an educational tool discourages innovation and may lead to blind adherence to current doctrine.

What war games can do best in an educational environment is provide a laboratory where players can practice wartime decision-making skills. War games help players examine the vast gulf between peacetime and wartime performance expectations. This will help the Air Force to train in the way it intends to fight. Add to this the fact that, during peacetime, war games are the only practical war experience most of the military can get at reasonable cost and you come up with a very convincing argument for their use.

A specific example of an operational game might modestly be called "global-thermonuclear war." Players of this game would represent the highest command levels for nuclear employment. In one application of this game, the commander in chief Strategic Air Command (CINCSAC), or other designated commanders, would play the role of the president of the United States for the purpose of deciding on a US nuclear response. The purpose of such a game would be to give these commanders as realistic exposure as possible to the decision-making environment of nuclear employment. The game need not be concerned only with strategic exchange but also might encompass tactical nuclear release in conjunction with convention. ' and chemical or biological attack.

A second example of a training and education operational game is global mobilization of national military resources. This could range from unopposed mobilization to reconstitution of conventional or nuclear forces following a nuclear strike. A major feature in such a game would be command and control. The game could be played across all the levels of the taxonomy. One purpose of the game would be to examine the interrelationships of the many activities

and the intricate coordination necessary for global mobilization. This game, which could offer a larger, or general-officer, perspective to participants, could be a vehicle for investigating the role of supporting commands in extended, low-intensity conflicts.

Operational Planning Applications

As pointed out earlier, FTXs involve considerable expense to move the equipment and personnel to a suitable location for the exercise. Because even simulated battles are expensive, it is important that the players derive maximum training benefit from the exercise. One way of ensuring that the FTX goes smoothly is to try out new ideas in a war game prior to implementation in the field. Similarly, when the FTX is over, participants might further benefit by applying a war game for added "what if" analysis of situations that developed during the exercise. In this context, a war game can serve as a multiplier to increase the benefits derived from exercises. The Reforger or Brave Shield exercises would appear to be targets of opportunity for this kind of game.

If there is one area of war plans that deserves special scrutiny, it is joint operations. Plans are created by professionals with a wealth of experience in their service branches to ensure that realistic assumptions guide all aspects. The areas where this process is most likely to break down are those where the least experience is available. Joint operations is such an area and there are many impediments to truly effective communication between planners in the separate services. War games can provide an opportunity to discuss these differences. Even more vividly, war games can demonstrate in very graphic terms some of the effects of misunderstandings.

The characteristics of war games that make them especially suitable for testing war plans are the reality and sense of involvement they bring to participants. These characteristics encourage in-depth thinking that can reveal secondary effects or other aspects of plans that participants might not otherwise consider. At the same time, there must exist in the hearts and minds of those using the games a healthy disregard for the accuracy of any predictions resulting from game play. There is a fine line between accepting war gaming as a useful tool and a suitable adjunct for brainstorming a problem by providing insight and blindly accepting changes to a plan based solely on results of a game. Any conclusions reached must take into account the nature of the game and the underlying model.

Research, Management, and Evaluation Applications

War games in this third application can cover a wide range of activities including the following: research and development of strategy, tactics, and doctrine; development and evaluation of battlefield support tools; and evaluation of potential commanders under stress, more controversial use.

The development of strategy, tactics, and doctrine can address any or all phases of deploying, employing, or sustaining military forces. Games here could cover the scope from one-on-one to global conflict. The effort need not be limited strictly to battlefield situations. Under this broad umbrella one might imagine experiments, for example, to assess the effects of organizational structures. These experiments might include evaluating the effect on Tactical Air Command of a new aircraft maintenance concept or the implications of various options for Air Training Command in a mobilization.

The global-thermonuclear war game, for example, could be used for research of crisis management in a nuclear environment. In such a game simulated political leadership would manipulate the military and political instruments of national power in an attempt to resolve a nuclear confrontation. The opening scenario of the game might or might not include the actual initiation of nuclear hostilities. Such an exercise would provide a tool for exploring nuclear stability, crisis management, and the role of information, or even information systems, in resolving international nuclear issues.

In a related research area, one could envision using a war-gaming center to develop and evaluate battle-support tools. With the advent of inexpensive and rugged microcomputers, there has been considerable interest in attempting to develop information and decision-support systems for field use. Testing of such tools might best be accomplished in the context of a war game where controlled conditions make scientific experiments with various systems possible.

The advantages and disadvantages of war games for these applications are similar to those cited for evaluation of war plans. The vividness of the simulated war experience encourages in-depth and creative thinking about war and war-related experiences. Again, experience and knowledge of the limitations of the game itself must temper conclusions.

An application that is sure to attract attention is the use of war games as a tool for evaluating officers. An opportunity presents itself here for a dual evaluation

format. On the first level, evaluation can take place for peacetime advancement in terms of the officers' ability to perform at their current jobs and in the jobs of their supervisors. On a second level, evaluation can take place in terms of the officers' ability to perform in a wartime environment. This is one way to address the dichotomy in the military mission discussed earlier. Although controversial, officer evaluation on the second level could provide additional information on officers' responses to the stress of simulated war.

A modular structure for a war game (mentioned in chapter 2) would facilitate the game's application to planning and evaluation. By structuring modular software elements along organizational lines, one can envision a game in which each software element has optional modules for either interactive or artificial intelligence play. Each software element would represent an organizational element so that a game could incorporate human decision making or use artificial intelligence modules depending on what elements are of particular interest in a given game. By organizing the software elements in a hierarchical fashion, either interactive or artificial intelligence play could be incorporated at various organizational levels, again depending on the interests in and goals for a particular game. For example, a game in which human players make tactical air allocation and base-level logistical decisions and artificial intelligence modules play other elements could be assembled by linking up the appropriate modules from a library of interactive and artificial intelligence modules. This would provide tremendous flexibility in creating games tailored to specific audiences.

Force Evaluation Applications

If, in terms of frequency of use, educational applications represent the preeminent use of war games, then force evaluation represents a close second. War games provide a forum from which to demonstrate the worth of a proposed weapon system, the necessity of a given force level, or the advantage of a particular force structure alternative. With the aid of a war game it is possible to demonstrate, in tangible terms, the effects of specific policy and budget decisions to show how they translate into specific military systems and further to demonstrate how the capability of these systems stacks up against enemy capabilities.

The problem is that war games are ill suited for making absolute assessments of situations. The myriad of assumptions, any of which can strongly affect the results, prevents the accurate prediction of outcomes for any of the

situations gamed. Where games do excel is in making comparative evaluations. Thus, a game is not particularly useful in determining if adding aircraft A or aircraft B to the Air Force inventory will ensure victory in a given scenario. On the other hand, a game can help in comparing aircraft A to aircraft B to measure their relative contributions. This comparison is possible because the same game, with the same assumptions, can be played while varying only aircraft A or aircraft B in the inventory. The measure of merit in this case is not the absolute outcome of either game but rather the difference between the outcomes in the two games. Taking the difference between two game outcomes diminishes the effects of bias inherent in the game's outcome.

Unfortunately then, war games can be of only limited help in answering a class of very important defense questions. Any question that has to do with how much defense is enough is ill suited to analysis by war game. Unfortunately too, this class of questions also seems ill suited to definitive answer by any other method. Given the mystical reverence shown by most people for results generated by computers, however, it is likely that war games will continue to be used to advocate specific defense policies and weapon systems. When the AFWC becomes operational, its personnel should be prepared for queries about providing analysis support of this kind.

Counteradvocacy Applications

The final area of application for an AFWC is suggested by the repeated findings reported in the literature and discussed in chapter 3 that many games lack essential documentation for the assumptions and techniques in them. This lack contributes to misuse of war games in the advocacy of certain positions. There are several roles that the AFWC could play to encourage the proper use of war games.

One role an AFWC could play is that of an inspector general (IG) for war games. In this capacity the AFWC would judge the adequacy of the documentation for a game. This application fits in well with the idea of using the AFWC as a repository for war-gaming models within the Air Force as discussed above. The familiarity of AFWC personnel with various war-game models would also allow the AFWC IG role to extend to review of the uses made of war game results. The AFWC could provide a second opinion on the adequacy of the war game experiments to the ultimate users of the information so obtained.

There is little doubt that independent review of the uses made of war game results would be beneficial. The AFWC

offers distinct advantages as a setting for performing such a function. The AFWC is one of three directorates in the Air University Center for Aerospace Doctrine, Research, and Education (CADRE). The other two directorates in CADRE are The Airpower Research Institute (ARI) and Air University Press (AUP). Within this single organization, then, exists the potential for the complete cycle of research (within ARI), testing (in the AFWC), and publishing (in AUP). This organizational embodiment of the scientific method forms an ideal backdrop for the IG function in war gaming. When combined with the concept of the AFWC as a war-gaming resource center for the Air Force, it offers the prospect of considerable synergism.

CHAPTER 5

SUMMARY AND RECOMMENDATIONS

The history of war gaming is replete with examples of misinterpretation and misuse. Wherever models, simulations, and games are used, the potential for abuse exists. The most common abuse occurs in attempts to use war games to predict outcomes in specific scenarios. War games are better used to construct realistic decision-making environments that simulate decision making under the uncertainty that is characteristic of war. The use of war games to stimulate discussion and thought about complex problems rather than to provide specific answers is more likely to generate useful ideas and is less likely to mislead participants.

Summary

The growth of computer technology has opened a broad avenue for advancement in computer-aided war gaming. The mass production of sophisticated graphics input and output devices means that equipment formerly quite expensive and available only in laboratories is now more readily accessible and affordable for use in war gaming. The simplified mechanics makes it possible for players to cope with more elaborate and more detailed war games.

Artificial intelligence offers the opportunity to automate echelons of command not of immediate concern to the game players. Thus, rule-based artificial intelligence programs could play both enemy and higher or lower level friendly commanders, allowing more realistic games with fewer players.

A modular gaming structure combined with artificial intelligence presents a unique opportunity to create an advanced war-gaming system. By structuring a game into modules, the potential exists to tailor a game to the specific interests of the players present without sacrificing realistic play for other portions of the game not represented by human game players. To do this, the gaming structure must allow substitution of artificial intelligence computer play for interactive human play within various subsystems of the game.

The characteristics of war games make them particularly applicable to an educational environment. As educational tools they need not be limited to traditional professional military education roles. Using war games as a medium, different decision-making environments can be created that are suitable for all levels of Air Force personnel. The synthetic history created by game play provides a unique learning situation for the participants.

War games outside the educational environment have serious shortcomings since the validity of any war-game model can not be assured. The most successful uses of war games depend on insight resulting from game play, not on absolute answers emanating from the game. War games are a useful brainstorming tool to aid in the generation of ideas. All applications of the CRES that go beyond using the war game to create decision situations, or structuring an environment to provide insight to decision-making situations, should be undertaken only with the greatest of forethought and with full realization of the limitations of war games for these other purposes.

The applications touched upon in chapter 4 are illustrative of the potential of the AFWC. Actual applications of operational gaming must be developed in concert with the customers of the AFWC. This involvement of the AFWC customers is essential because no application independently developed by the AFWC can properly address the genuine needs of the MAJCOMs. Thus, the customers must participate in the planning process for implementation of phase three of CRES as soon as practicable. The recommendations section of this chapter includes some specific suggestions on how to do this.

This report has discussed in some depth both the advantages and disadvantages of war games and suggested a range of potential applications for the AFWC. What follows here are recommendations deemed most important by the author from the vantage point of having completed this research.

Recommendations

The CRES program management office (PMO) is well on its way to developing an initial war-gaming capability for use in the Air University PME environment under phase one the CRES. The required activities for implementation of phase one are relatively clear as the games envisioned represent evolutionary changes from existing games. In addition, the PME schools at Air University, who are the customers for phase one, have been well integrated into the process of defining requirements for the proposed system.

The goals of phase two of the CRES remain to be translated into specific actions and war-gaming systems. Doing so clearly will require intimate cooperation between the PMO and the senior service schools. Informal contacts are now being made that will facilitate negotiation of the formal agreements necessary for successful culmination of phase two. The war games for this phase, like those of phase one, will be evolutionary; rooted in successful games used at the individual war colleges.

It is in phase three of the CRES that selection of specific activities necessary to achieve an operational war-gaming capability become less clear. As was pointed out in chapter 1, the operational gaming mission of the AFWC is qualitatively different from the PME mission. There are fewer precedents for what is to be created than in the cases of phases one and two. This presents both a tremendous challenge and an opportunity for the CRES PMO.

This author believes that phase three of the CRES represents a potential to develop a hierarchical, modular, war-gaming system that would allow linking various combinations of interactive and artificial intelligence modules to create custom war games. The advantages of such a system include the ability to tailor a game to a particular audience or need and, as a byproduct of the systems modularity, to create a system that can easily be maintained and updated. The latter is simply a matter of correcting individual existing modules and creating new modules as needed.

The technologies requiring development to bring such a modular, hierarchical system to fruition are artificial intelligence, modular gaming, and hierarchical modeling. Developments using these elements such as the Rand Strategic Assessment Center (RSAC), the Army Model Improvement Program (MIP), and the Joint Chiefs of Staff Joint Analytic Warfare System (JAWS), should be closely monitored by members of the PMO. In some cases it may be appropriate for the CRES PMO to provide money for the development of projects that promise significant payoff for the proposed integrated AFWC system.

MAJCOM Involvement

If there is one overriding consideration to ensuring the success of phase three of CRES, it is the need for involving the MAJCOMs in the development effort. The author proposes a three-pronged effort to secure that involvement.

At the highest level, there should be a presentation at the Corona conference soliciting cooperation of the

commanders in CRES phase-three development. This presentation should emphasize benefits of the AFWC, not on a grand scale, but rather as a tool to help find pragmatic solutions to real problems. Recognizing that this cooperation is necessary but not sufficient, there should be a second effort aimed at middle-level managers.

A briefing outlining both the benefits and pitfalls of operational gaming should be assembled and taken to the MAJCOMs. This presentation should outline the goals of the operational gaming phase of CRES and emphasize the importance of the involvement of the MAJCOMs in defining the actual implementation of phase three. The briefing should contain several important points that would allay fears expressed by some individuals contacted in the course of this research.

One point to be emphasized is that the CRES is not intended to usurp any analysis role played by organizations at the MAJCOMs--a politically sensitive issue with some organizations. It is also a difficult issue because, without specific applications for phase three to point to, it is complicated to explain just what will be done and hence demonstrate that phase three does not impinge on the prerogatives of in-house analysis organizations. It would be useful to come up with a definition of operational gaming that helped to make this distinction clear.

A second point to be made in this MAJCOM briefing should be that the CRES is intended to help solve problems, not grade the performance of individuals. This misconception of the purpose of the CRES is fueled perhaps by a common misidentification of the Command Readiness Exercise System as the Command Readiness Evaluation System. Again, the lack of known and specific applications for phase three of the CRES allows individuals to imagine that their worst fears will come true when the CRES comes on line.

Since some major problems for the CRES result from a lack of specific applications, an obvious point to make in the MAJCOM briefing is a plea for active cooperation in defining specific operational games that are useful and acceptable to those concerned. The ultimate goal of the presentation should be to make the MAJCOM audience feel responsible for the success of operational gaming.

The third tine of the three-pronged effort to involve the MAJCOMs follows up on the theme of MAJCOM responsibility. The CRES users conference, which has met but once, should be rehabilitated. I recommend that the users conference operate on two levels: as a forum for dissemination of information concerning the CRES program and as a working group responsible for refining the

definition of phase three requirements. As an information forum, the conference would be of value to representatives from the planning and operations organizations within the MAJCOMS.

Operational Game Descriptions

Acting as a working group, the CRES users conference is one of three recommended initiatives for beginning the process of defining actual operational games to be implemented in phase three. In order to accomplish the working group functions, the CRES users conference should include working-level individuals in addition to supervisors. Semiannual or annual meetings should be supplemented with additional information exchange among the working group. One means to help coordinate the efforts of geographically separated members of the working group would be through the use of the defense data network (DDN), the military extension to the advanced research project agency network (ARPANET). The exchange of electronic mail between members of the working group would encourage a continuous cross-flow of information and maintain, between formal meetings, the involvement of participants in CRES activities.

A second suggested initiative for defining operational games involves each MAJCOM sending an individual to the AFWC for a one year research project to define requirements for a specific operational war game. The research project would be under the umbrella of the CADRE Visiting Research Fellow program. The MAJCOM Visiting Research Fellow could use, as part of the research project, the results of directed research projects in the Air War College and the Air Command and Staff College. Using a Research Fellow offers the advantage to the MAJCOM of giving complete control over the development of the specification to the MAJCOM and ensuring that specifications of operational games of particular interest to a individual MAJCOM will be available for inclusion into phase three of the CRES.

The third initiative to define operational games for the phase three is an in-house, CADRE effort to define a particular game. This project could serve as a prototype for other efforts. The selection of an operational game for this effort must be determined by the expertise that is locally available. An an example, CADRE might define an operational game to exercise tanker operations for deployments, particularly in the Pacific theater. A brief summary of such an operational game is in the appendix. The presence of other individuals in CADRE with specialized experience may offer specific targets of opportunity for other in-house efforts.

The actual product of any of the three initiatives would be a definition of an operational game in a form complete enough to be incorporated by the CRES PMO into the contractor specifications for the software development for phase three of the CRES. By bringing several of these initiatives to fruition, the CRES PMO can have specific, useful, and detailed operational games with which to begin phase-three development. A latent resource to be considered for use in any game specification effort are retired senior military personnel. This pool of talent can bring a wealth of experience to a game design effort.

APPENDIX

The game envisioned to exercise Pacific deployments would model the movement of tactical aircraft from CONUS to WESTPAC. The geographic setting recommends itself because of the experience of one of CADRE's current senior research fellows, Lt Col Fred J. Reule. Lt Col Reule's previous responsibilities for providing inflight refueling support for all trans-Pacific aircraft movements makes him a uniquely knowledgeable in this area. Clearly the models developed to implement this game could, with different data, represent a European deployment. The elements to be incorporated in this model would include detailed models of tanker and receiver aircraft performance; the support facilities that can be made available to a deployment, including runway, ramp, maintenance and servicing capacities; C^3; crew, and aircraft flow; seasonal wind patterns; and geographic distances.

Such a model would be a tool with which to test alternative policies for employment of assets to discern the effects on timeliness of aircraft delivery, reliability, safety, and resource consumption. In addition, the players could ascertain the effects of limitations of ramp space, fueling capacity, and other factors. at various potential intermediate points. Extensions to the model would allow for estimating the costs and benefits associated with such rules as those requiring tanker escort for the entire over-water portions of deployment, the value of providing HF radio communication for deploying fighters if escort is not provided, the need for dedicated and/or secure communication links, and testing of alternative organizational structures in support of such deployments.

The goal of using the operational game would be to allow for planning tanker operations that are responsive to needs. Current deployment plans are very detailed and, precisely because of this, cover only a small portion of possible contingencies. Should the plan be executed, unanticipated contingencies would soon cause the real-world situation to deviate significantly from the plans. This deviation throws those attempting to execute the plan back on their own devices in attempting to accomplish the ends. In general, it is desirable to make robust plans and implement flexible systems that can be readily adapted to changing circumstances rather than to program rigid responses for specific cases. The operational game would provide a test bed for proposed plans and systems.

Envisioned as an essential part of this game would be a real-time, stand-alone, computerized flight planning system. The flight planning system would allow game players to readily prepare flight plans, including fuel off-loads for tanker aircraft, to serve as inputs to the game. Such a system would be a particularly useful tool to the operational commands and an integral part of a flexible and robust tanker operations plan.

The operational game would provide peacetime training for the individuals responsible for executing deployments under wartime conditions. The game could provide training in operating the system that is not available today due to differences between peacetime and wartime deployment rules.

Developing such a system would be a test for the CRES operational gaming concept. Success in developing a complete specification for this game would be a step in determining the feasibility of developing comparable systems. In addition, this specification could serve as a useful prototype, indicative of the level of detail needed to specify the elements of an operational game.

Producing a detailed description of such a model would require the cooperation of the planning and operations staffs of SAC, TAC, and MAC to ensure that realistic assumptions were used. Extending a Pacific model to incorporate the European scenario would require additional resident expertise and/or theater coordination visits.

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